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Forensic Science Review's Professional Review and Commentary (R&C) section highlights contemporary issues and events in the profession of forensic science. To contribute updates or commentary or to recommend books for review, please contact Mike Baylor (mbaylor@nc.rr.com), Jeff Teitelbaum (Jeff.Teitelbaum@wsp.wa.gov), or Ray Liu (rayliu@uab.edu).

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Forensic Science in UK. Part II: Forensic Science Provision in Scotland and Nothern Ireland

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This report is the second part of a series on "Forensic Science in the UK" [1]. The focuses of this part are on historic and current forensic science provisions in Scotland and Northern Ireland.

Delivery of Forensic Services in Scotland

The Scottish Police Authority (SPA) is the responsible body for providing forensic services to support operational policing in Scotland. The SPA was established under the Police and Fire Reform (Scotland) Act 2012 [2], replacing the Scottish Police Services Authority (SPSA) and other areas of policing. This act states that, "The Authority must provide forensic services to the Police Service, the Police Investigations and Review Commissioner, and the Lord Advocate and procurators fiscal".

Historical Development. Historically, a range of different support services were in operation to support Scotland's eight police forces: Central Scotland Police Dumfries and Galloway Constabulary, Fife Constabulary, Grampian Police, Lothian and Borders Police, Northern Constabulary, Strathclyde Police and Tayside Police, and the Scottish Crime and Drug Enforcement Agency (SCDEA). Four laboratories based in Dundee, Aberdeen, Glasgow, and Edinburgh provided these services in different areas of forensic science and merged when the SPSA was formed. This model was not based on a competitive market but provided an integrated service to the police [3].

SPSA's origins can be found in an initial review of police force structures commissioned by Scottish ministers in 1999 [4]. A group of representatives from the Scottish Executive, the Association of Chief Police Officers in Scotland (ACPOS), and the Convention of Scottish Local Authorities (COSLA) recommended a unification of the different forces. The original report emphasized the need to keep the existing number of police forces in Scotland but also brought attention to the fact that savings could be made by bringing together and extending the support services that were already provided on a national basis.

Finally, SPSA was created in 2007 under the Police, Public Order, and Criminal Justice (Scotland) Act 2006. The main rationale behind it was to establish savings in the delivery of forensic services but also to provide a unified service in Scotland. This was controversial at the time as the transfer of members of staff and assets from the previously independent individual forces was not considered well managed, as raised in some reports [5]. Little time was given to forensic services to be transferred from when the Act was passed to the start date of operations. The short timescales and lack of information on what staffing, equipment, and assets used to deliver the existing forensic services were to be transferred hindered the process. Also, the reluctance by some forces to agree on what particular services were to be transferred made the process slow. This was the general feeling recorded in the report and audit conducted by the Auditor General for Scotland in 2010. In particular, the transfer of scene-of-crime staff to the forensic services was only agreed after ministerial intervention late in 2006.

The audit also showed that SPSA's difficulties during its initial stages were complicated by frequent changes in both the board and its senior executives. Since these early years, SPSA has improved services in a number of areas and stands as an efficient forensic service at present. The amalgamation of forensic services as a consequence of the unification means that Scotland now possesses a fully integrated national "crime scene through to court" service.

Current Status. The new Police Scotland officially started their operations on April 1, 2013 under the Police and Fire Reform (Scotland) Act 2012. Scotland's new unified police force replaces eight regional constabularies and is now the UK's second-largest force after the Metropolitan police.

One of the central pivotal points of the Police and Fire Reform (Scotland) Act is that forensic services do not directly answer to the Chief Constable. These services are now independently managed and delivered as part of the

SPA, which guarantees a high degree of independence and impartiality. A recent inspection of SPA Forensic services by the HM Inspectorate of Constabulary in Scotland [6] stated that independence from the police service and other parts of the criminal justice system was highlighted to them by all stakeholders as being fundamental to the service provided. Four sources backing up this principal are stated, the main one being a US National Academy of Sciences report on Forensic Sciences in 2009 [7], which found and stated that forensic services should be independent from law enforcement.

Forensic services for example in biology, chemistry, and crime scene areas such as drug analysis, fingerprint, and DNA analysis, managing the national DNA database, information and communication technology (ICT) services, training, learning, and other development for new recruits, police officers and staff at the Scottish Police College were under the SPSA jurisdiction. Forensic services are now the responsibility of the SPA, with other key elements (e.g., ICT) covered by Police Scotland. A Forensic Service modernization program began in 2010 and completed in 2013, resulting in five distinct functions: biology and DNA, physical sciences, scene examination and imaging, business support, and quality.

The responsibility for the governance of the police in Scotland lies directly in three authorities: Scottish ministers, the police authority or a joint police board responsible for setting police budgets, and the Chief Constable of Police Scotland.

The current operational aspects of the SPA are outlined in [6], and briefly summarized as follows: scene examination is delivered from 17 satellite offices, 4 of which are located within laboratory facilities (Aberdeen, Dundee, Edinburgh, Gartcosh). Two of the laboratory centers (Gartcosh and Dundee) are described as high-volume centers, with a firearms unit based in Gartcosh. The high-volume centers deal with drugs, but the Aberdeen facility has additional staff to deal with this too, presumably for geographical and time-dependent reasons. High-volume centers for biology exist in Dundee and Glasgow.

Death investigation is directed by the Crown Office and Procurator Fiscal Service (COPFS), through the Scottish Fatalities Investigation Unit (SFIU), with forensic pathology work generally being carried out by staff associated with the Universities of Glasgow, Edinburgh, and Dundee. Forensic Toxicology for Scotland is carried out at NHS Grampian in Aberdeen (for the Grampian and Northern regions) and the University of Glasgow for all other regions. The SPA Laboratory in Edinburgh focuses in forensic toxicology out with death investigations (for example, alcohol/drugs in road traffic situations).

Delivery of Forensic Services in Northern Ireland

A forensic science laboratory has been in operation in Northern Ireland for more than 50 years. This laboratory was opened in 1956 as the Department of Industrial and Forensic Science, and was independent from the laboratories in England and Wales. The forensic science laboratory was integrated into the Northern Ireland Office as a division in 1976 and later renamed as the Northern Ireland Forensic Science Laboratory, which became an executive agency of the Northern Ireland Office in 1995. The name was changed to Forensic Science Northern Ireland in April 2000. By 2002, plans were initiated to position the laboratory for the introduction of a more commercial marketplace following similar developments in England and Wales – this was initially to take the form of Trading Fund status. On April 12, 2010, as a result of the Devolution of Policing and Justice in Northern Ireland, Forensic Science Northern Ireland (FSNI) became an executive agency within the Department of Justice (DoJ). The transfer of the agency to the Northern Ireland Government coincided with a commitment by the justice system to maintain a locally based forensic science laboratory within the public sector.

FSNI provides a scientific support service for the Police Service of Northern Ireland (PSNI), the State Pathologist's Department (SPD), the Office of the Police Ombudsman for Northern Ireland (OPONI) and Her Majesty's Revenue and Customs (HMRC). Also, it delivers scientific advice for the Public Prosecution Service (PPS) and the legal profession and offers objective expert testimony to the Courts. It is located in Carrickfergus, County Antrim, and operates as a supply-financed agency of the DoJ under a net running-cost regime.

This allows FSNI to increase expenditure in-year, provided it is matched by in-year receipts. Its role is to provide objective scientific advice and support to enhance the delivery of justice. FSNI currently employs approximately 200 staff, all civil servants, of whom roughly 65% are scientists directly involved with casework.

The demand for forensic science services reached a peak with the escalation in violence during "The Troubles". A second more recent spike in demand has occurred with the introduction of new technologies, most notably high-tech biometrics (for example, forensic DNA).

As an executive agency of the DoJ, FSNI has its own Executive Board and Chief Executive. The independence of FSNI's scientific opinion is paramount to guarantee an independent assessment of the forensic evidence and it is safeguarded through the operational independence of the Chief Executive. This independence is translated in

the way the agency reports individual cases under investigation or before the courts. The purpose of FSNI is set out in its corporate mission, the vision and goal that is focused around delivering effective and impartial forensic science demonstrated through a timely, integrated, and value-for-money approach. Part of the operational model for the provision of forensic services (including forensic science) in England and Wales continues to have a strategic relevance for Northern Ireland.

Very recently, an independent inspection report by the Criminal Justice Inspection Northern Ireland (CJI) [8] has called for the criminal justice system to develop a more joined-up approach to forensic services to meet current and future forensic requirements.

In all aspects, FSNI has the characteristics of a traditional state (national) laboratory offering a wide range of services. So far, it has been the primary provider of forensic science to the PSNI (90% of its operational work) and has also generally facilitated the brokering of work to other providers where required — this is generally due to a lack of specialism and/or lack of capacity in FSNI. FSNI also provides a wide range of services, under annual Service Level Agreements (SLAs) with criminal justice organizations including the PSNI and SPD. The bulk of forensic science demand originated from the PSNI are prioritized in the order of national security, serious harm, and community confidence — the latter relates to volume crime (for example, burglary).

It has divided its core scientific work into two distinctive but related processes: (a) laboratory services that undertake the extraction and analysis of forensic exhibits and (b) reporting services that interpret the results and provide reports to its customers and to the justice system. The range of specialist services is spread across 12 scientific operational sections (DNA evidence recovery units; Analytical Services; Digital Electronics; Alcohol, Drugs & Toxicology; Biology; Firearms; Fires, Explosives & Microchemistry; physical methods, Specialists Fingerprint Unit (SFU) & Questioned Documents (Qdocs); Road Traffic Collision; Trainee Court reporting Officers; ICT).

The agency is regularly audited by the CJI to guarantee that high standards are met [9]. While this inspection is primarily focused on the delivery of forensic science services by FSNI, it is also necessary to consider the broader delivery of forensic services. Also, forensic science and policing is overseen by The Northern Ireland Assembly under Section 49(2) of the Justice (Northern Ireland) Act 2002 and The Northern Ireland Act 1998 (Devolution of Policing and Justice Functions) Order 2010) by the DoJ.

Since devolution, the approach adopted by DoJ and the criminal justice agencies in Northern Ireland has been to strengthen the position of FSNI as the sole (public sector) local provider of forensic science. Only in 2014, FSNI provided a wide range of services from crime scene to court that includes about 9,000 reports on 6,000 cases per year, which in turn has been based on an analysis of approximately 20,000 exhibits. In order to maintain standards and guarantee quality of service, the FSNI quality management system has been externally accredited by the United Kingdom Accreditation Service (UKAS). There is also an assurance from its customers and the courts that the quality of its services (for example, advice) and products (for example, reports) have also been good. Sustaining these standards and level of satisfaction has been a notable achievement [9].

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The International Symposium on Human Identification: A Dynamic Platform to Promote DNA Forensics

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Few would have predicted that the arguably unglamorous job of the forensic scientist would achieve such a degree of mainstream awareness and appeal. Fueled in part by the widespread popularity of television shows like CSI, Forensic Files, and NCIS among others, forensic science has been embraced in mainstream culture and is now recognized as the most powerful tool that law enforcement has at its disposal.

But long before the field fascinated Hollywood, many of the real-life heroes of forensics have gathered for the longest-running and largest conference in the world focusing on DNA typing for human identification. For the past 28 years, the International Symposium on Human Identification (ISHI) has brought together forensic professionals from around the world to discuss and debate issues that are important and sometimes controversial in the field, to share new ideas and to collaborate to advance forensic science. More than 900 participants representing more than 40 countries will attend this year's ISHI29, to be held September 24–27, 2018, in Phoenix, AZ. Forensic experts will present on a range of topics relevant to the DNA typing community during the two-and-a-half-day general session. The symposium will also feature 12 workshops on a variety of topics scheduled before and after the plenary talks.

The Original ISHI

The first ISHI was held in 1989 during an exciting time in the nascent field of DNA typing. In the middle of the 1980s, a young scientist named Alec Jeffreys made a discovery that would have a profound influence on the field of forensics. He discovered a method to visualize genetic differences in mammalian DNA, starting with DNA from a seal, and then applying this discovery to discriminate between the genetic profiles of human beings.

Jeffreys's technology would be considered cumbersome and rudimentary compared to today's standards. The data generated by his method appeared as smudgy blobs of DNA visualized on photographic plates. The process to arrive at "DNA fingerprinting" was laborious, involving radioactive materials and hours of processing time, and it gave statistical results that would not be considered impressive in today's courtrooms.

DNA typing was first successfully used to assist in an immigration case confirming a maternal relationship between a UK citizen and her son who was petitioning to be allowed into UK. Jeffrey's technique was later used in a criminal case to solve a double rape and murder. This was the Colin Pitchfork case, which involved a DNA dragnet and the surprise exoneration of a man who confessed to the crime but was innocent. The sensational case was dramatized in the book *The Blooding* by Joseph Wambaugh.

For a short while, Jeffreys's lab at Lister Institute in Leicester was the sole facility in the world to work on criminal cases using the DNA-typing technology. Beginning in 1987, commercial companies like Cellmark, academic institutions, national police departments, and crime labs became interested in using the new DNA-typing technology for aiding criminal investigations.

This was the backdrop for the first ISHI, convened in Madison, WI, in 1989. Why Madison? The city is where the biotech company Promega Corporation got its start 40 years ago. Among the most promising products the company began manufacturing in the late 1980s were VNTR and RFLP probes that could be used in the emerging field of DNA forensics. Bill Linton, Promega founder and CEO, organized the first symposium with the goal of bringing together the small community to discuss important issues and advance forensic science technologies.

Several participants who attended the meeting in 1989 described the forensic field of the day as a kind of "Wild West" where there was boundless enthusiasm about the technologies but very little practical direction for how to bring DNA analysis into mainstream practice. Animated discussion ranged from standardizing protocols, calculating and reporting statistics, and perhaps most importantly, overcoming the challenge of getting DNA results accepted in a court of law. The first ISHI was optimistically organized to bring the forensic community together to address all of these issues.

The attendees at that winter meeting in Madison numbered less than 100. They came from all around the world and many who participated at the inaugural meeting are among the most accomplished people in the forensic community today. Alumni from the first conference include Ronald Acton, Michael Baird, Robert Bever, Charles Brenner, Bruce Budowle, Thomas Callaghan, Debra Endean, Ian Evett, Rockne Harmon, Peter Neufield, Antti Sajantila, John S. Waye, David Werrett, and Ray White, among others. (If you attended the first ISHI in Madison, I invite you to contact me at carol.bingham@promega.com so I can add your name to the list that we'll publish at the 30th symposium.)

The field was wrestling with a number of challenging issues, as evidenced by the agenda from the 1989 meeting. One topic foremost in the mind of the community was

the question of DNA admissibility in court. The phrase, "DNA Wars" was coined to reflect the conflict that existed between those representing the new field of DNA typing and the court system, which was reluctant to accept the results. The methods used to generate profiles were complex and difficult to explain in the courtroom. Because the technology was brand new, there was heated debate concerning the reliability of DNA testing, in part due to an absence of standards and consistency in reporting errors.

In addition to DNA admissibility, new techniques such as use of mitochondrial DNA, the use of Y-STRS and the merits of using capillary electrophoresis vs. gel sequencing provoked much discussion. During the early days of DNA typing, single-locus probes were state of the art, providing limited power of discrimination. It was not until the early 1990s that multiplex kits were introduced, which exponentially expanded the discriminatory power of DNA analysis, spurring additional debate on how to correctly calculate and report the results.

ISHI Today

Much has changed over the course of nearly three decades. DNA technology has advanced to a degree that might have seemed like science fiction back in 1989. Now DNA is routinely analyzed from touch samples, physical characteristics like hair and eye color can be ascertained using SNP technology, and the DNA databases established in the early 1990s have grown to contain more than 13 million DNA profiles.

While the landscape in DNA typing for forensics has advanced significantly over the past decades, the focus and vision for ISHI has remained constant. Subject matter experts in various forensic disciplines come together to learn from each other, to network, and to see the latest technologies on display. Optional workshops held in conjunction with the symposium cover timely topics relevant to the work of the forensic DNA community.

At ISHI29 in Phoenix, a full-day workshop, Systems Thinking and DNA Mixtures: Dynamic Models Optimization, Validation and Inference, will introduce systems thinking with demonstrations on applying a systems approach to forensic DNA mixture interpretation, optimization, and validation. Topics to be covered include validation of the DNA interpretation pipeline containing probabilistic genotyping software, focusing on current and forthcoming OSAC/ASB and SWGDAM mixture interpretation validation, and verification standards and guidelines. The workshop will be taught by a talented team of forensic experts including Catherine Grgicak, Robin Cotton, Charlotte Word, and John Butler, who has written seminal books on the field of forensics.

John Collins will lead a workshop titled, High-Impact Leadership for Forensic Laboratory Professionals. Collins was previously director of the Michigan State Police forensic laboratory system and is the author of the newly released book, *HR Management in the Forensic Science Laboratory* (Academic Press: San Diego, CA; 2018). His workshop will provide insight on: How to think like an HR manager, lower anxiety and raise morale among employees, respond to allegations of malpractice or misconduct, and maximize employee performance with minimal effort.

Forensic laboratories are not immune to quality issues. Recognizing and addressing anomalies in the lab is of critical importance. Successfully researching and identifying the "root cause" of an adverse event or failure provides valuable information for the prevention of future events. Charlotte Word, whose experience in forensic science began in the early years of the technology, will lead an interactive workshop titled, Root Cause Analysis in Forensic Laboratories in Principle and Practice. Speakers with first-hand experience will discuss lessons learned from root cause analyses performed in crime laboratories and detail the factors contributing to adverse events. Attendees will participate in an interactive exercise using real-life case examples and practical tools for root cause mapping that can be taken back to the laboratory.

Grants, of course, make the work of forensics possible. The National Institute of Justice (NIJ) will hold a workshop to discuss the grant-writing outlook, including how to read an NIJ solicitation and what key areas to focus on when writing a grant. Chuck Heurich and Heather Waltke will explain the NIJ funding cycles, deadlines, and relevant legislation that pertain to DNA capacity and backlog-reduction grants in a workshop called, NIJ's DNA Capacity and Efficiency Programs: Program Updates, Grant Management and Navigating Performance Measures.

This is just a sampling of the dozen workshops that will be offered before and after this year's symposium. Other conference highlights include the general session program, which begins Tuesday morning and concludes at noon on Thursday. Confirmed speakers include the Keynote, Andrew Hessel, who will discuss his work on writing genetic code, which he hopes will lead to advances in human health and longevity. A panel will discuss the pros and cons of using genealogical databases to solve criminal cases as illustrated by the recent "Golden State Killer" case. The panel will debate whether the value of solving cold cases through this unorthodox method should trump the privacy concerns raised by accessing personal profiles contained in public databases. Policy updates will be given on the CODIS (Combine DNA Index System) and NDIS (National DNA Index System) databases by Doug Hares, NDIS Custodian for the FBI; Ted Hunt, Senior Advisor to the Attorney General on Forensic Science, will announce a new forensic DNA quality assurance measure for laboratories.

Additional talks will be selected from abstracts submitted by the forensic community prior to the June 17 deadline. All abstracts will be reviewed by an independent, external committee of forensic experts and selected based on the novelty of the work and perceived interest to the forensic community.

More than 100 scientific posters will be presented during two designated poster and exhibits sessions. These presentations will cover every aspect of the use of DNA typing for human identification. Past presentations have addressed new technologies for sample preparation, analysis of various body fluids, improvements to data yield, quality, and interpretation, laboratory information systems, data analysis, population statistics, and more. Poster abstracts are due by July 15 and are to be submitted via the official conference website. All posters and oral abstracts will be included in the on-line Proceedings published after each symposium.

The International Symposium on Human Identification is a great place to see new product introductions. More than 50 companies that provide products and services for the forensic community will be exhibiting at the symposium. Conference attendees can see new technologies firsthand on the exhibit floor and participate in free product showcases by select vendors on Tuesday evening and Wednesday morning.

Networking continues to be a compelling reason to attend the annual symposium. Many participants have found new positions through contacts made at ISHI. Others appreciate finding collaborative opportunities at the conference or meeting others in the field who are experiencing the same challenges. Conference participants can mingle at the opening welcome reception, optional bowling party, breakfasts in the exhibit hall, focused topic lunches, and a dinner event at Corona Ranch. All networking events are included in the conference registration fee with the exception of the bowling event.

The venue for this year's meeting is the Phoenix Convention Center. Register for the conference before August 1 and receive discounted fees on the workshops and general session. More information on the conference, venue, workshops, agenda, and speakers can be found on the official conference website, *www.ishinews.com*.

If you are not able to participate this year, mark your calendar for next year's 30th ISHI. ISHI30 will be held in beautiful Palm Springs, CA, September 23–26, 2019. Keep up with the plans for this milestone event by subscribing to the website updates at *www.ishinews.com*.

We hope you'll join us at this year's ISHI or a future meeting to network with the true heroes of forensics, the men and women who are working to advance the science of DNA typing.

National Forensic Laboratory Information System

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Background. As the primary agency for enforcing the controlled substances laws and regulations of the United States, the Drug Enforcement Administration (DEA) strives to develop information sources on the prevalence and distribution of drugs commonly available and used, as well as emerging drugs. The DEA's Diversion Control Division was established with the mission to prevent, detect, and investigate the diversion of controlled pharmaceuticals and listed chemicals into the illicit market, while ensuring an adequate and uninterrupted supply for legitimate needs.

Established in 1997, the National Forensic Laboratory Information System (NFLIS), a program of the DEA's Diversion Control Division, represents an important resource in monitoring illicit drug abuse and trafficking [1]. The primary purpose of NFLIS is to provide accurate and chemically verified data in support of drug scheduling. NFLIS supplements and complements other data sources such as the National Survey on Drug Use and Health and the Poison Control Center database. NFLIS data are used to support drug scheduling decisions and to inform drug policy and drug enforcement initiatives nationally and in local communities around the country.

Here we provide a history and overview of the NFLIS program and major activities and resources provided by NFLIS. We also provide the community with updates on the status of NFLIS and its recent enhancements.

NFLIS-Drug. Available NFLIS data reflect the results from drug chemistry analyses conducted by federal, state, and local forensic laboratories across the country (NFLIS-Drug). The NFLIS-Drug participation rate, defined as the percentage of the national drug caseload represented by laboratories that have joined NFLIS-Drug, is more than 98%. This includes 50 state systems and 102 local or municipal laboratories or laboratory systems, representing a total of 280 individual laboratories. NFLIS-

Drug is voluntary, with moderate assistance provided to laboratories with special needs. Laboratories report data in a convenient format, and data are standardized.

NFLIS-Drug was built on the concept of minimal burden to participating laboratories, which has been one of the reasons for a successful and growing program. NFLIS staff work closely with each laboratory, the laboratory's information technology department, and laboratory information management system (LIMS) vendors, as available, to facilitate data submissions. This collaboration helps to implement no-cost standardized reporting solutions to minimize burden on the laboratories. Each month, laboratories submit a set of nine core data items and nine secondary data items of results from drug chemistry analysis cases (**Table 1**).

Table 1. NFLIS-Drug core data items submitted by participating laboratories

Core data items	Secondary data items
Laboratory case number	Submitting agency case no.
Laboratory submission number	Name of submitting agency
Laboratory item or exhibit number	Origin of drug
Submission and receipt dates	Name of manufacturer
Location of submitting agency	Packing or markings
Form of material	Color of evidence
Quantity	Drug purity
Date case was completed or reported	Secondary drugs identified
Substances identified	Noncontrolled substances identified

Survey. Early in NFLIS-Drug data collection, tremendous insight into the diversity of laboratory organizations, capabilities, procedures, and policies was needed to provide the additional context by which the results of NFLIS-Drug could be understood. The first Survey of Crime Laboratory Drug Chemistry Sections, fielded in 1998, was critical in the short and long terms because it (a) supported the creation of the NFLIS-Drug data collection by providing key laboratory information; (b) was the basis for strengthening the existing laboratory database with descriptions of the organizational contexts in which the drug case analyses were conducted; and (c) provided an important basis from which an informed national sample was drawn. Moreover, the 1998 and subsequent surveys (2002, 2004, 2008, and 2013) continue to provide the information to maintain the universe of crime laboratories in the US. Overall, 90% of crime laboratories completed the 2013 survey, which highlighted that drug chemistry caseloads had greatly or moderately increased for nearly one-third (32%) of responding laboratories [2]. The turnaround time greatly or moderately increased from the previous year for 41% of responding laboratories, whereas 16% reported that their turnaround time greatly or moderately decreased [2]. According to responding laboratories, the two major contributors to backlogs were increase in emerging drugs (61% of laboratories) and loss of staff (50% of laboratories) [2].

Regarding the third benefit, the survey was the primary source for the number of drugs analyzed annually by individual forensic laboratories and laboratory systems, which was important because the number of drugs analyzed — or caseloads — was determined to be the best size measure for sample selection. Along with laboratory type (state, municipal, or county), the caseload size measure served as one of two stratification variables in the initial selection of randomly selected laboratories for recruitment into NFLIS-Drug. Caseload information was also a major determining factor in identifying certainty laboratories based on size, region, geographic location, and other special characteristics for early NFLIS-Drug recruitment. The initial national sample provided the basis for how data could be responsibly reported in the early years of NFLIS-Drug via national estimates.

The next Survey of Crime Laboratory Drug Chemistry Sections will be fielded in 2019 to current NFLIS-Drug participants and other eligible crime laboratories across the country. The DEA plans to convene an expert panel in the summer of 2018 to inform the survey development. Like past surveys, the next survey will support the creation of national estimates and will be used to update the profiles of laboratories participating or eligible to participate in NFLIS-Drug. Survey results also provide unique information about forensic laboratories and drug chemistry analyses that are used in supporting further development of NFLIS-Drug. These results will be presented to the public in a format similar to the 2013 NFLIS-Drug survey.

Available Resources. In 2018, the NFLIS team created the NFLIS-Drug Public Resource Library that is on the NFLIS website and accessible to the public. The library includes resource documents, static tables, and published maps. The resource documents include NFLIS citation guidance, guidance on writing about NFLIS public data table findings, frequently asked questions and answers, and a publication on NFLIS statistical methodology. The static data tables include national estimates and State counts for the most frequently identified drugs and state counts for fentanyl and fentanyl-related substances, synthetic cannabinoids, and synthetic cathinones from 2007 through 2016. DEA plans to release this standard set of tables once annual data are ready for publication.

The NFLIS-Drug published maps provide a collection of high-quality, predefined map images that can be

downloaded for use in reports, presentations, and other documents that require high-quality map graphics. The DEA identified these static, high-resolution map images as being useful for repeated reference. All maps are available as JPG and PDF files.

Starting in 2000, NFLIS published quarterly reports from participating NFLIS-Drug laboratories. To give perspective, for the first quarterly report in June 2000, there were 18 state laboratory systems (81 individual laboratories) and 23 local laboratories [3]. In 2001, NFLIS-Drug presented data on national estimates. Since then, NFLIS-Drug publishes annual [4] and midyear [5] reports on national and regional estimates of the 25 most frequently identified drugs; national and regional trends of specific drugs; and data on major drug categories such as narcotic analgesics, tranquilizers and depressants, anabolic steroids, phenethylamines, and synthetic cannabinoids. Each year, NFLIS-Drug also reports on special topics of interest to the DEA and the public in its series of special reports [6] and briefs [7]. To date, DEA has published 63 NFLIS-Drug reports. In addition, NFLIS presents data at national conferences annually.

Data Query System (DQS). The secure area of the NFLIS website includes the NFLIS-Drug DQS, which was designed to provide the DEA and other federal, state, and local laboratories participating in NFLIS-Drug with an analytic tool that can provide timely and detailed results on the types, prevalence, and location of emerging and other diverted drugs. The DQS allows remote analysis to be conducted down to a specific case so that laboratories can have access to their own data and summary data. At an aggregated level, the information can, in turn, inform drug control and drug scheduling policies and efforts across the country.

Only participating laboratories, their designees, and the DEA are granted access to the DQS. The NFLIS website uses the industry standard communications protocol, HTTPS, to establish secure, encrypted connections to the DQS.

Moving forward, the DEA intends to continue to enhance the NFLIS-Drug DQS and its usefulness to participating NFLIS-Drug laboratories and welcomes feedback on the system's usefulness and usability, as well as ideas for possible improvement.

NFLIS-MEC and NFLIS-Tox. Over the years, the DEA has supplemented NFLIS-Drug data by collecting ad hoc information about deaths from medical examiner/coroner offices (MECs) and the drugs that may have been present at the time of death, as well as drug testing information from toxicology laboratories (TLs). These two sources have been instrumental in boosting the DEA's intelligence on new and/or emerging drugs that have not yet been seen or seized by law enforcement or tested by forensic crime laboratories. Such intelligence has been increasingly important given the emergence of the synthetic drugs (e.g., synthetic opiates, synthetic cannabinoids, synthetic cathinones) that are produced in clandestine laboratories and are constantly evolving. A recent NFLIS-Drug publication on synthetic cannabinoids and synthetic cathinones showed, for example, that in 2009, 2 synthetic cannabinoids and 5 synthetic cathinones were reported to NFLIS; by comparison, in 2015, 84 different synthetic cannabinoids and 35 different synthetic cathinones were reported to NFLIS-Drug [6]. From January 2015 through December 2016, a total of 57,308 fentanyl and fentanyl-related substance reports were identified by state and local forensic laboratories in the US [7].

The DEA is enhancing its efforts to combat diversion and identify new and emerging drugs of misuse and abuse by expanding NFLIS to include two additional drug surveillance data collections, one for death data from MECs (NFLIS-MEC) and another for drug testing–related data from TLs nationwide (NFLIS-Tox). Both data collections will complement NFLIS-Drug data and will provide the DEA with continuous data on drug trends to assist with drug control actions.

Given more than 20 years of NFLIS-Drug success, NFLIS-MEC and NFLIS-Tox will be developed and maintained in a manner similar to NFLIS-Drug.

Feasibility Study. To be effective in systematically collecting data for and maintaining NFLIS-MEC and NFLIS-Tox, a thorough understanding of MECs' and TLs' operations and data reporting capabilities was needed to design these two new NFLIS programs. Specifically, information was needed on MECs' and TLs' capabilities to report requested information, including their information management systems, and the definitions and classification criteria used for key measures as necessary. Especially relevant are the resources available across these MECs and TLs because these factors may facilitate or impede systematically reporting key death data and drug toxicology results into a national data system.

NFLIS staff conducted a feasibility study in 2016 to obtain the perspectives of MEC and TL stakeholders regarding the feasibility of, logistics of, and interest in participating in a long-term national surveillance system that collected death data from MECs and drug toxicology test results from TLs. Site visits were conducted at nine MECs and nine TLs across the United States from May to October 2016. The diverse pilot sites were selected to inform short- and long-term requirements for the two data collections to be successfully implemented. A qualitative,

semi-structured interview designed to collect information from MECs and TLs about overall readiness, interest, and infrastructure available to participate in NFLIS was developed and used during the feasibility study. Across the MECs and TLs, 51 interviews were conducted (**Table 2**).

Some of the major findings from the feasibility study were that

- Toxicology request frequencies and practices varied widely across the MECs based on laws, budget, and policies;
- Staffing and budgetary constraints affect decisions for toxicology testing, instrumentation updates, and ability to validate additional drugs on their instrumentation;
- Given the recent opioid epidemic, participating in a credible data system that collects quality standardized data was viewed as important for MECs and TLs;
- All the MECs and TLs collected most of the core data items and generally could report those data electronically; and
- There was consensus that having an automated reporting routine that would extract the data items would be ideal and would facilitate participation in NFLIS-MEC and NFLIS-Tox.

Findings from the MEC and TL feasibility study were presented at *The 2017 Joint Meeting of the Society of Forensic Toxicologists and The International Association of Forensic Toxicologists* [8].

Table 2. Description of respondent positions, by pilot site visit type

Respondent type	No.
MEC sites	27
Medical examiner or deputy medical examiner	6
Coroner or deputy coroner	5
Laboratory director	3
Toxicologist	6
Data analyst	2
Information management system or information technology administrator	3
Administrative support	2
TL sites	24
President, chief executive officer, director, chief operating officer, or vice president	6
Forensic pathologist	2
Laboratory supervisor	11
Laboratory technician	2
Chemist	2
Administrative support	1
Total pilot site respondents	51

2017 Surveys. The data collected from the MEC and TL feasibility study provided some key insights into items included on both surveys. The surveys were designed to collect key information about caseload, toxicology requesting practices, capability of collecting and reporting the core data items, and resource needs. These surveys will be instrumental in generating the information needed for building robust databases; for developing a sound foundation for appropriate sampling; for providing valuable data for recruitment; and for providing important context for data collection, analysis, and reporting.

Survey responses were collected via mixed-mode data collection (web, mail, and telephone). Data collection began in June 2017 and ended in October 2017. NFLIS staff performed several actions to increase survey responses, including making verification calls to confirm MEC and TL contact information and points of contact; prompting call reminders; and calling nonrespondents to obtain responses to two critical questions. NFLIS staff also reached out to several organizations to encourage participation.

There were 231 TLs completing the survey (60%). The response rate increased to 68% (267 TLS) based on nonresponse follow-up calls to obtain critical items. Of the 267 TLs responding, 39% (104 TLs) were in the South; 24% (64 TLs) were in the West; 19% (52 TLs) were in the Midwest; and 18% (47 TLs) were in the Northeast. Almost 6 in 10 (57%) TLs that responded to the survey were publicly funded, whereas 43% were privately owned and operated. Of the 226 eligible respondents that answered the question about accreditation, 43% were accredited by the ANSI-ASQ National Accreditation Board; 36% were accredited by the Clinical Laboratory Improvement Amendments; 26% were accredited by the College of American Pathologists; and 15% were accredited by the American Board of Forensic Toxicology. Caseload was determined by the number of toxicology requests responding TLs received in 2016. Of the 256 TLs that provided caseload information, close to 80% reported caseloads between 0 and 49,999 in 2016. TLs were asked to indicate their average turnaround time, in days, for completion of a toxicology case, excluding turnaround time for alcohol-only cases. Across the 210 TLs responding to this question, the overall average turnaround time was 36.5 days.

Of the 2,145 MECs that were sent a survey, 45% provided complete surveys. Upon data collection completion, the response rate increased to 60% based on nonresponse follow-up calls to obtain critical items. Of MECs that provided information on the total population of the jurisdictions their offices served, 39% served small jurisdictions (population less than 25,000); 44% served medium jurisdictions (population 25,000 to 249,999); and 18% served large jurisdictions (population greater

than 250,000). MECs were asked if their offices used an off-site TL, and nearly all (96%) indicated that they did. Overall, 785,923 human death cases were referred to and 497,395 human death cases were accepted by MECs responding to the survey. Case completion was defined as completion of a death certificate. Average turnaround time to complete a case was 31 days. Of MECs that provided information related to which types of accreditation they currently held, nearly three-quarters reported no accreditation. The most commonly reported accreditations were a state accreditation (12%); accreditation by the National Association of Medical Examiners (9%); and accreditation by the International Association of Coroners & Medical Examiners (6%). Of MECs that answered the question on computerized or manual information systems, nearly equal percentages reported having a computerized/networked system (32%); using a manual record-keeping system (31%); or using a partially computerized system with some manual record-keeping (30%).

Table 3 lists the MEC and TL core data items that NFLIS-MEC and NFLIS-Tox plan to collect. Results from the surveys indicate that most MECs and TLs capture these core items. As for NFLIS-Drug, NFLIS staff will work closely with each participating MEC and TL, their information technology department, and LIMS vendors, as available, to facilitate data submissions.

Results from the NFLIS-MEC survey were presented at *The 2018 American Academy of Forensic Sciences Annual Meeting* [9]. Additional national presentations are planned for dissemination of the NFLIS-MEC and NFLIS-Tox survey, along with a publication similar to the 2013 Survey of Crime Laboratory Drug Chemistry Sections [2].

Recruitment. All MECs and TLs are encouraged to participate in the NFLIS-MEC and NFLIS-Tox surveillance programs. Like NFLIS-Drug, these are voluntary programs in which each MEC and TL will follow a memorandum of understanding with the DEA, and all information will remain secured and anonymous to specific MECs and TLs.

If you are interested in enlisting in NFLIS-MEC or NFLIS-Tox as an early recruit, please contact NFLIS at NFLIS@usdoj.gov.

Table 3. NFLIS-MEC and NFLIS Tox core data items

MEC core data items	TL core data items
Cause of death	Requesting office type or agency
Age of decedent	Case type
Sex of decedent	Requesting office location (city/county, ZIP)
Case ID or unique identifier	Case ID or unique identifier
Date of death	Sex of individual
Manner of death	Age of individual
Location of injury (county, ZIP)	Drugs and metabolites confirmed
Submitting agency	Concentration with units for confirmed results
Date of final death record	Sample matrix used for confirmed results
Known prescription drugs decedent was prescribed	Legitimately prescribed medications in patient's profile
Autopsy performed	

References

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7. US Drug Enforcement Administration (Diversion Control Division): *NFLIS Brief: Fentanyl and Fentanyl-Related Substances Reported in NFLIS, 2015–2016*; US Drug Enforcement Administration: Springfield, VA; 2017.
8. Pressley D, Polk A, Wong L, Boos T, Smiley-McDonald H, Moore K, Ropero-Miller J, Heller D, Ancheta J, Weimer B, et al.: The National Forensic Laboratory Information System (NFLIS): Expansion Feasibility Study for Drug-related Mortality and Toxicology Findings; Presentation — *Joint Meeting of the Society of Forensic Toxicologists and the International Association of Forensic Toxicologists*; Boca Raton, FL; 2017 (January 2018).
9. Pressley D, Polk A, Wong L, Boos T, Smiley-McDonald H, Moore K, Burnette E, Ancheta J, Kunta N, Heller D, et al.: Preliminary Findings from DEA's National Forensic Laboratory Information System (NFLIS) Medical Examiner/Coroner Office Survey; Presentation — *70th Annual Meeting of the American Academy of Forensic Sciences*; Seattle, WA; February 2018.

Upcoming Events

WCABC-2018: World Conference on Analytical & Bioanalytical Chemistry
July 23–24, 2018; Alimara Barcelona Hotel
Barcelona, Spain

International Association for Identification — 2018 International Educational Conference
July 29–Aug. 4, 2018; Henry B. Gonzalez Convention Center
San Antonio, TX, US

TIAFT 2018: 56th Annual Meeting of the International Association of Forensic Toxicologists
Aug. 26–30, 2018; Ghent International Convention Center
Ghent, Belgium

ICFS 2018: 20th International Conference on Forensic Sciences
Aug. 27–28, 2018; Holiday Inn Paris Montparnasse
Paris, France

Current Trends and Challenges in Alcohol, Drugs and Traffic Safety — The International Council on Alcohol, Drugs and Traffic Safety (Regional Conference)
Sept. 1–4, 2018, Brevnov Monastery
Prague, The Czech Republic

Australian & New Zealand Forensic Science Society — 24th International Symposium on the Forensic Sciences
Sept. 9–13, 2018, Perth Convention and Exhibition Centre
Perth, Australia

International Forum for Drug & Alcohol Testing — 2018 Conference
Sept. 3–4, 2018, The Marker Hotel
Dublin, Ireland

Midwestern Association of Forensic Scientists — 47th Annual Fall Meeting
Sept. 16–21, 2018; Crowne Plaza Hotel — Union Station
Indianapolis, IN, US

The Robert F. Borkenstein Course on the Effects of Drugs on Human Performance and Behavior
Sept. 17–21, 2018; Science History Institute
Philadelphia, PA, US

Northwest Association of Forensic Scientists — 2018 Annual Conference
Sept. 17–21, 2018; Red Lion Hotel Boise Downtowner
Boise, ID, US

ISHI 2018: 29th International Symposium on Human Identification
Sept. 24–27, 2018; Phoenix Convention Center
Phoenix, AZ, US

Southwestern Association of Forensic Scientists — 40th Annual Conference
Sept. 29–Oct. 4, 2018; Horseshoe Casino Hotel
Shreveport, LA, US

Society of Forensic Toxicologists — Annual Meeting
Oct. 7–12, 2018; Hyatt Regency Minneapolis
Minneapolis, MN, US

SCIX-2108: Annual Meeting of Analytical Chemistry and Spectroscopy Societies
Oct. 21–26, 2018; Atlanta Marriott Marquis
Atlanta, GA, US

Northeastern Association of Forensic Scientists — 2018 Annual Meeting
Oct. 23–27, 2018; Sagamore Resort on Lake George
Bolton Landing, NY, US

2018 International Conference on Forensic Nursing Science and Practice
Oct. 24–27, 2018; Peppermill Resort Hotel Reno
Reno, NV, US

California Association of Toxicologists — 2018 Fall Meeting
Oct. 27–28, 2018; Venue to be announced
Bakersfield, CA, US

Forensic@NIST 2018
Nov. 7–8, 2018; NIST Campus
Gaithersburg, MD, US

3rd Caparica Christmas Conference on Sample Treatment
Dec. 3–6, 2018; Aldeia dos Capuchos Golf & Spa
Caparica, Purtugal

American Academy of Forensic Sciences — 71st Annual Meeting
Feb. 18–23, 2019; Baltimore Convention Center
Baltimore, MD, US

PITTCON Conference and Expo
March 17–21, 2019; Pennsylvania Convention Center
Philadelphia, PA, US

American Society of Crime Laboratory Directors — Annual Symposium
May 19–21, 2019; St. Louis Union Station Hotel
St. Louis, MO, US

The Association of Firearm and Tool Mark Examiners — 51st Annual Meeting
May 26–31, 2019; Venue to be announced
Nashville, TN, US

ADVANCING THE PRACTICE OF FORENSIC SCIENCE IN THE US — UPDATE

After the US National Research Council published "Strengthening Forensic Science in the United States: A Path Forward" *(see* https://www.ncjrs.gov/app/publications/abstract.aspx?ID=250103*) in 2009, the National Institute of Standards and Technology (NIST) and US Department of Justice (DOJ) committed to a number of initiatives to strengthen the practice of forensic science.*

NIST conducts research to advance the forensic sciences, supplies forensic laboratories with physical reference standards and data to help ensure accurate test results, and administers the Organization of Scientific Area Committees for Forensic Science (OSAC), which facilitates the development of science-based standards for forensic practice.

In partnership with NIST, the Center for Statistics and Applications in Forensic Evidence (CSAFE) conducts research to develop statistical methods to accurately analyze and interpret pattern and digital evidence. The CSAFE team provides education and training in these new methods to forensic practitioners, members of the judicial community, and other stakeholders nationwide.

The National Institute of Justice (NIJ) is the federal government's lead agency for forensic science research and development as well as for the administration of programs that facilitate training, improve laboratory efficiency and reduce backlogs. Within the realm of forensic science, NIJ's aim is to improve the quality and practice of forensic science through innovative solutions that support research and development, testing and evaluation of technology, information exchange, and the development of training resources for the criminal justice community.

The Forensic Technology Center of Excellence (FTCoE), a program of the NIJ, serves as a resource for both practitioners and developers. It assists in the transition of forensic technology from applied research into practice; and in conducting knowledge transfer and outreach.

The "Professional Review and Commentary" section of FSR has published previous "Updates" for both NIST (since January 2014) and for NIJ's FTCoE (since July 2014). The current semiannual "Updates" from these agencies and their programs are included in this issue.

National Institute of Standards and Technology (NIST) and NIST-Sponsored Programs

National Institute of Standards and Technology Forensic Science Updates

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New NIST Forensic Tests Help Ensure High-Quality Copies of Digital Evidence

Data found on a suspect's computer, cell phone, or tablet can prove to be crucial evidence in a legal case. A new set of software tools developed at the National Institute of Standards and Technology (NIST) aims to make sure this digital evidence will hold up in court.

The software suite, referred to collectively as *federated testing tools*, is designed to help law enforcement and forensic practitioners with a critical early step in evidence collection: Making a copy of the data from a seized electronic device. Because a suspect's guilt or innocence can hang in the balance, both the prosecution and the defense must agree that the digital forensic process did not introduce any unseen errors into the data, and that the methods they are using work as expected.

Extracting and copying data is a risky process because of the rapidly shifting digital landscape that we and our devices inhabit. Confronting the practitioners are all the differences in data and format that can exist between one device and the next — because of the sheer number of different manufacturers, and because of the frequent software updates pushed to various makes and models.

"It's hard to keep up," said Barbara Guttman, one of the suite's developers at NIST's Computer Forensics Tool Testing project. "You don't want to risk your copying software failing when you try to get data from some new computer that is critical to your case. So, we created these tools to help ensure that the copying software works effectively and transparently."

The federated testing tools allow authorities to run tests in advance on their digital forensic software to make sure ahead of time that it will not fail them when a suspect's personal computer, media, or device arrives in the forensic science lab. Guttman describes the suite as the three most critical tools for evidence acquisition and preservation, each addressing one aspect of the copying process.

One tool tests software for copying computer disks, while another tests mobile device data extraction software. These two test protocols were available previously, but the suite is now completed with a new third test for "write

blockers", which are a sort of one-way valve for data-copying software. An effective write blocker allows data to flow only from the seized device to the copying computer, not the other way around. Later updates to the suite will address additional forensic functions, Guttman said.

The full suite is a freely available Linux file that anyone can download and burn to a blank CD. They can use the disk to boot their workstation and test their copying tools via a user-friendly interface. The NIST software also allows different forensics labs to exchange the results of their tests with each other, so that they can share the burden of exploring how well a copying method works on a specific platform and operating system. Running copying software through its paces generates a report that disparate organizations can share among themselves or with the world, allowing them to indicate whether they found anomalies during the testing or not.

"Pooling these traceable results will mean less work for any given lab or organization," Guttman said. "We don't require they share the tests, but a rising tide should raise all boats." Guttman cautioned that the tools will not ensure that a copying or digital forensic process is flawless, only that the results of the job are clearly visible to anyone. "Evidence doesn't have to be complete to be admissible," she said. "The key here is that copying does not introduce errors into the data that no one can see." Interest in federated testing will go beyond law enforcement agencies, Guttman added. Any organization that performs forensics, such as civil law firms and corporate enforcement offices, will find a use for the test suite.

How Good a Match Is It? Putting Statistics into Forensic Firearms Identification

On February 14, 1929, gunmen working for Al Capone disguised themselves as police officers, entered the warehouse of a competing gang, and shot seven of their rivals dead. The St. Valentine's Day Massacre is famous not only in the annals of gangland history, but also the history of forensic science. Capone denied involvement, but an early forensic scientist named Calvin Goddard linked bullets from the crime scene to Tommyguns found at the home of one of Capone's men. Although the case never made it to trial — and Capone's involvement was never proved in a court of law — media coverage introduced millions of readers to Goddard and his strange-looking microscope.

That microscope had a split screen that allowed Goddard to compare bullets or cartridge cases, the metal cases a gun ejects after firing a bullet, side by side. If markings on the bullets or cases matched, that indicated that they were fired from the same gun. Firearms examiners still use that same method today, but it has an important limitation: After visually comparing two bullets or cartridge cases, the examiner can offer an expert opinion as to whether they match. But they cannot express the strength of the evidence numerically, the way a DNA expert can when testifying about genetic evidence.

Now, a team of researchers at NIST has developed a statistical approach for ballistic comparisons that may enable numerical testimony. While other research groups are also working on this problem, the advantages of the NIST approach include a low error rate in initial tests and that it is relatively easy to explain to a jury. A full description of authors' approach is available in *Forensic Sci Int* 284:15; 2018 (*https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5961495/*).

When comparing two cartridge cases, the NIST method produces a numerical score that describes how similar they are. It also estimates the probability that random effects might cause a false positive match — a concept similar to match probabilities for DNA evidence. "No scientific method has a zero error rate," said John Song, a NIST mechanical engineer and the lead author of the study. "Our goal is to give the examiner a way to estimate the probability of this type of error so the jury can take that into account when deciding guilt or innocence."

The new approach also seeks to transform firearm identification from a subjective method that depends on an examiner's experience and judgment to one that is based on objective measurements. A landmark 2009 report from the National Academy of Sciences and a 2016 report from the President's Council of Advisors on Science and Technology both called for research that would bring about this transformation.

The Theory Behind Forensic Ballistics. When a gun is fired, and the bullet blasts down the barrel, it encounters ridges and grooves that cause it to spin, increasing the accuracy of the shot. Those ridges dig into the soft metal of the bullet, leaving striations. At the same time that the bullet explodes forward, the cartridge case explodes backward with equal force against the mechanism that absorbs the recoil, called the breech face. This stamps an impression of the breechface into the soft metal at the base of the cartridge case, which is then ejected from the gun.

The theory behind firearm identification is that microscopic striations and impressions left on bullets and cartridge cases are unique, reproducible, and therefore, like "ballistic fingerprints" that can be used to identify a gun. If investigators recover bullets or cartridge cases from a crime scene, forensic examiners can test-fire a suspect's gun to see if it produces ballistic fingerprints that match the evidence. But bullets and cartridge cases that are fired from different guns might have similar markings, especially if the guns were consecutively manufactured. This raises the possibility of a false positive match, which can have serious consequences for the accused.

A Statistical Approach. In 2013, Song and his NIST colleagues developed an algorithm that compares three-dimensional surface scans of the breech-face impressions on cartridge cases. Their method, called *congruent matching cells,* or CMC, divides one of the scanned surfaces into a grid of cells, then searches the other surface for matching cells. The greater the number of matching cells, the more similar the two surfaces, and the more likely they are to have come from the same gun.

In their recent study, the researchers scanned 135 cartridge cases that were fired from 21 different 9-mm pistols. This produced 433 matching image pairs and 4,812 nonmatching pairs. To make the test even more difficult, most of the pistols were consecutively manufactured.

The CMC algorithm classified all the pairs correctly. Furthermore, almost all the nonmatching pairs had zero matching cells, with a handful having one or two due to random effects. All the matching pairs, on the other hand, had at least 18 matching cells. In other words, the matching and nonmatching pairs fell into highly separated distributions based on the number of matching cells. "That separation indicates that the probability of random effects causing a false positive match using the CMC method is very low," said coauthor and physicist Ted Vorburger.

A Better Way to Testify. Using well-established statistical methods, the authors built a model for estimating the likelihood that random effects would cause a false positive match. Using this method, a firearms expert would be able to testify about how closely the two cartridges match based on the number of matching cells, and also the probability of a random match, similar to the way forensic experts testify about DNA.

Although this study did not include enough test-fires to calculate realistic error rates for actual casework, the study has demonstrated the concept. "The next step is to scale up with much larger and more diverse datasets," said Johannes Soons, a NIST mechanical engineer and coauthor of the study. With more diverse datasets, researchers will be able to create separate models for different types of guns and ammunition. That would make it possible to estimate random match rates for the various combinations that might be used in a crime.

Other groups of researchers are working on ways to express the strength of evidence numerically, not only for firearms but also fingerprints and other types of pattern evidence. Many of those efforts use machine learning and artificial intelligence-based algorithms to compare patterns in the evidence. But it can be difficult to explain how machine-learning algorithms work. "The CMC method can be easily explained to a jury," Song said. "It also appears to produce very low false-positive error rates."

Free Software Can Help Spot New Forms of Fentanyl and Other Illegal Drugs

Forensic chemists can download the software from the NIST website. Fentanyl, the synthetic drug that is driving a nationwide overdose epidemic, is not only a killer. It's also a shape shifter. Illicit chemists are constantly cooking up new forms of fentanyl, each with a slightly different chemical structure, stymieing law enforcement and putting users at greater risk. To control fentanyl, which mimics heroin but is far more potent, forensic chemists need to identify it. But when they encounter a new type of fentanyl, called a fentanyl analog, it will not yet be in the chemical databases they use to identify illegal drugs. Now, NIST has released a free software tool to help.

The NIST tool contains an algorithm for searching chemical databases that can recognize new fentanyl analogs even if there are no matches in the database. This method, called *hybrid similarity search*, works in conjunction with with mass spectrometry and was recently described in *Analytical Chemistry* (*https://pubs.acs.org/doi/abs/10.1021/acs.analchem.7b03320*). "If you search for one compound, you will find all the compounds that have a similar chemical structure," said Arun Moorthy, a NIST postdoc fellow and mathematical statistician who worked on the algorithm. "That should help law enforcement and public health authorities react more quickly when a new and deadly drug hits the streets." The method also works with synthetic cathinones — more commonly known as "bath salts" — synthetic marijuana and other drugs.

When crime lab chemists receive a bag of powder that might contain illegal drugs, their first step, like any criminal investigator, is to fingerprint the suspect. In this case, they get "molecular fingerprints" of whatever is in the powder, then run those fingerprints against a database of known suspects to look for a likely match. To get those fingerprints, they insert a sample of the powder into a mass spectrometer, which bombards the sample with electrons. This shatters the molecules into fragments. Then it sorts those fragments by their weight, or mass, to produce a "mass spectrum" — a unique pattern of vertical lines that can be used as a molecular fingerprint. One of the most commonly used databases of molecular fingerprints is maintained by the Scientific Working Group for the Analysis of Seized Drugs, or SWGDRUG. If forensic chemists search that database, which currently contains 88 fentanyl analogs, and get a hit, they will do further tests to confirm the identification. But if they don't get a hit, the substance will remain unknown.

Why do illicit chemists invent new fentanyl analogs? One reason is that tweaking the structure of the compound can enhance its narcotic effect, producing what users

might consider a better high. Another reason is to dodge law enforcement. Before presenting evidence about a new analog in court, forensic chemists need to discover it and work out its chemical structure. "Putting a new molecule in the books takes time, and before you know it, there's another one out there," said Sandra Rodriguez-Cruz, a senior research chemist with the Drug Enforcement Administration's Southwest Laboratory in Vista, CA. "It's a Whack-a-Mole game."

To create a new analog, illicit chemists change some of the atoms in the molecule while leaving the core structure intact. They might add a chlorine atom to one branch or remove a hydrogen atom from another. This almost always changes the compound's fingerprint by shifting some of the lines in the mass spectrum. "Our algorithm corrects for those shifts, so you can find related compounds," said Stephen Stein, the NIST research chemist who oversaw the development of the algorithm. An experienced chemist can also correct for those changes manually. But the manual method takes time and has to be done separately for each known compound that the unknown might be related to.

"The concept is intuitive to chemists, but it has never been captured in an algorithm before," Moorthy said. Now that it has, a computer can churn through an entire database looking for related compounds. If you're a chemist, you can try it out yourself. Hybrid similarity search is already built into the NIST 17 MS Search software, which you may already own. If not, download it from the NIST webpage, *https://chemdata.nist.gov/dokuwiki/doku.php?id=chemdata:nist17*. Copy a database such as SWGDRUG into the same folder, then run the program and submit the mass spectrum for an unknown compound.

The program will return a list of the most closely related compounds. If that list contains fentanyl or any of its analogs, the unknown might be a fentanyl analog as well. That list can also give you a head start on elucidating the new compound's chemical structure. "Hybrid search is not the silver bullet that will solve the opioid epidemic, but it is a very useful tool," Rodriguez-Cruz said. "If you have a difficult molecule, it can speed up your workflow significantly."

OSAC Releases an Online Lexicon for the Forensic Sciences

The forensic sciences encompass dozens of disciplines, each with its own history and vocabulary. As a result, a word might mean one thing to forensic anthropologists, for example, but something else to forensic document examiners. To help facilitate clear communication across the many disciplines, the Organization of Scientific Area Committees for Forensic Science (OSAC) has created a Lexicon of Forensic Science Terminology, which can be accessed from the OSAC website.

The *OSAC Lexicon Initiative* started in 2016, when OSAC's Forensic Science Standards Board (FSSB) tasked all OSAC units with identifying and collecting existing terminology related to their forensic science discipline. The end result is a consolidated, searchable lexicon organized by discipline. The terms and definitions come from the published literature, including documentary standards, specialized dictionaries, Scientific Working Group (SWG) documents, books, journal articles, and technical reports. In addition, the OSAC subcommittees generated or modified many definitions.

FSSB Chair Steve Johnson noted that, "Our goal was to get the OSAC work product out for public consumption, but this is a living document. OSAC plans to add new terms, remove terms, consolidate duplicate entries, verify sources of nonverified terms, and reach consensus on more OSAC Preferred Terms." Going forward, OSAC units should reference the current OSAC Lexicon for definitions when drafting or revising standards, and they should avoid creating new definitions unless substantive changes to the existing lexicon are warranted.

Other terminology initiatives within OSAC include developing discipline-specific terminology standards designed for publication by Standards Developing Organizations (SDOs). Two of these terminology standards are already available from the American Academy of Forensic Science's Academy Standards Board (ASB):

- ASB Technical Report 025, *Crime Scene/Death Investigation — Dogs and Sensors — Terms and Definitions*, First Edition (*https://asb.aafs.org/wp-content/uploads/2017/12/025_TR_e1_2017.pdf*). This document, which provides standard terms and definitions used in the detection dog community, promotes consistency across jurisdictions and relieves the judicial system of conflicting terms and definitions.
- ASB Technical Report 033, *Terms and Definitions in Bloodstain Pattern Analysis,* First Edition, 2017 (*https://asb.aafs.org/wp-content/uploads/2017/11/033_TR_e1_2017.pdf*). This document presents a list of recommended terms and definitions for bloodstain pattern analysis, including bloodstain pattern types and related concepts.

In addition, ASTM International is developing a draft terminology standard produced by the OSAC Fire Debris & Explosive Subcommittee. *WK56998 Terminology Relating to the Examination of Explosives*, has been submitted to ASTM E30.01 Criminalistics Subcommittee and is in balloting for approval.

Other existing terminology standards in forensic science include *ASTM E1732-17 Standard Terminology Relating to Forensic Science*, which the ASTM E30 Committee on Forensic Science recently determined will become the master terminology for all ASTM E30 documents (of which there are more than 50). ASTM's

E30.12 Digital and Multimedia Evidence Subcommittee also has a published terminology standard**,** *E2916-13 Standard Terminology for Digital and Multimedia Evidence Examination***.**

OSAC will continue to refine the Lexicon and to draft terminology standards for submission to SDOs. The release of this lexicon database for forensic sciences marks a milestone in the effort to help the many disciplines speak the same language.

Center for Statistics and Applications in Forensic Evidence Updates

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The Center for Statistics and Applications in Forensic Evidence (CSAFE) comprises an interdisciplinary team of more than 60 researchers from four universities. We conduct research in statistical and probabilistic foundations of pattern evidence and digital evidence that can be applied to the forensics field in a variety of ways. The CSAFE team works to build a statistically sound and scientifically solid foundation for the analysis and interpretation of forensic evidence to grow competence in the forensic sciences and legal communities, and bring together forensic practitioners and other stakeholders through educational and training opportunities. We also educate and train forensic practitioners, legal professionals, and other stakeholders on how to use, interpret, and communicate these new methods.

The information below highlights a sample of current CSAFE research and education initiatives led by our team. Additional accomplishments in other forensic science disciplines will be discussed in subsequent issues of *Forensic Science Review*. Visit our website *www.forensicstats.org* to learn more about how CSAFE is increasing the scientific and statistical foundations of forensic evidence.

New Public CSAFE Dataset Increases Accessibility of Bloodstain Patterns

In light of a recent National Academies of Science, Engineering, and Medicine report calling for forensic science reform, CSAFE researchers are developing more accurate methods for bloodstain pattern analysis. To advance the scientific basis of this field, access to large amounts of bloodstain patterns produced under controlled conditions is key. CSAFE researchers have answered this call by combining statistical learning techniques with fluid dynamics principles to develop a new state-of-the-art dataset of bloodstain patterns. The dataset is now publicly available to the forensic science community, researchers, and educators in "Data in Brief" (*https://www.sciencedirect.com/science/article/pii/S2352340918301902*).

Researchers built the high-resolution data set of 61 blood spatter patterns using controlled and carefully documented experiments corresponding to forensic beating situations. The CSAFE dataset enables researchers to test crime scene reconstruction models, allowing the identification of region of origin of blood spatter and generation mechanism such as beating or shooting. Armed with this information, researchers can begin to quantify previously unknown error rates associated with bloodstain pattern analysis. The ultimate goal of this project is to improve accuracy in courtroom testimony.

In addition to furthering essential research efforts, the CSAFE dataset facilitates improved dissemination of blood spatters for teaching and instructional purposes. Production and transport of blood spatters is cumbersome, and blood sourcing and handling involve logistical obstacles and safety risks. These barriers limit the availability of data to new scientists, thus restricting their education. The new CSAFE dataset increases access to quality training materials by providing blood pattern analysis instructors with a safe set of spatters ready to be printed for their classes.

Our team is committed to moving science forward by generating quality data and sharing results with the broader forensics community. The CSAFE dataset, recently published in "Data in Brief", is based on experimental design and methods that are readily reproducible and available to create additional blood spatters. Together, forensic scientists, researchers, and educators can build off the current CSAFE dataset to advance the scientific foundations of bloodstain pattern evidence analysis methods.

CSAFE Develops Fully Automatic Method for Comparing Cartridge Case Images

CSAFE researchers are addressing the need for objectivity in firearm analysis techniques. Our team has created a fully automated, open-source method for comparing breechface marks on cartridge cases. This CSAFE method focuses on 2-dimensional optical images and consists of an image analysis algorithm to compute measures of similarity. Additional CSAFE efforts on algorithms for comparing 3-dimensional breechface images will be discussed in future updates.

Current technology for automated matching of 2-dimensional cartridge breechface images requires the use of a proprietary technology. The matching process produces a score that has no known interpretation apart from allowing the ranking of matched images. There are no established methods to describe the error rates of such matching algorithms. This leaves examiners unable to quantify the weight of the evidence in the courtroom.

The CSAFE algorithm improves on existing methodology by adding additional preprocessing steps. Selecting breechface marks have previously been done manually by the examiner, who is operating the system, has the potential to introduce examiner-level variability in the comparisons. CSAFE researchers can now automatically select the breechface marks, thus reducing the subjectivity of the process.

Our new method also removes the effects of differences in depth of the cartridge case base that are circular in nature; this can also be described as circular symmetry. The CSAFE algorithm now corrects the resulting differences in brightness that previously affected the quality of the image. These new steps result in a demonstrable improvement in accuracy on images obtained from controlled test fires.

CSAFE advancements in breechface analysis enable fast and reliable matching of cartridge images, decreasing the level of effort by examiners. The automated CSAFE method computes a probability of obtaining the observed similarity score just by chance, allowing examiners to report a measure of uncertainty in court rather than simply relying on subjective opinions. The developed statistical model can also be used for blind verification in crime laboratories.

As a publicly available resource, the forensic science community is able to utilize the CSAFE breechface analysis method to continue improving objectivity and accuracy in this field. The CSAFE algorithm can be found in the "Datasets and Tools" (*https://forensicstats.org/resources/datasets-tools/*) section of the CSAFE website.

Visit the CSAFE Website for Webinars Addressing Diverse Forensic Science Topics

In order to expand the reach and impact of our research, CSAFE invites the forensic science community and other scientists and researchers to participate in our webinars focused on new forensic science research, findings, and applications. We encourage you to view past webinars on our website "Education Center" (*https://forensicstats.org/forensic-scientist-education-center/*). Visit our events page (*https://forensicstats.org/events/*) to learn about upcoming webinar topics and register to participate. Below are a few recent webinars now available to the public.

"Explaining Source Conclusions to a Lay Audience" (Dr. William Thompson, University of California, Irvine). View this webinar to explore what social science research reveals about the effectiveness of various evidence analysis explanation techniques. Learn strategies for communicating results in reports and testimony to a lay audience.

"Panel Discussion with NIST Researchers and the CSAFE Team on the Likelihood Ratio" (Panelists: Dr. Alicia Carriquiry, Iowa State University; Dr. Steve Lund and Dr. Hari Iyer, National Institute of Standards and Technology; Dr. Hal Stern, University of California, Irvine; Dr. William Thompson, University of California, Irvine; David Kaye, Pennsylvania State Law School). Join the CSAFE team and NIST researchers to learn more about the impact of the likelihood ratio in a legal context and what likelihood ratios mean to lay audiences. Also discussed is the role of expertise in the courtroom and what sensitivity analysis tells us about the likelihood ratio approach to forensic evidence.

View CSAFE "Forensics, Statistics and Law" Conference on YouTube to Learn Ways the ForensicScience Community Can Improve Evidence Analysis

"Forensics, Statistics and Law", a March 2018 CSAFE conference held at University of Virginia School of Law, marked the 25th anniversary of the US Supreme Court's decision in *Daubert v. Merrell Dow Pharmaceuticals Inc*. This case reshaped how judges evaluate scientific and expert evidence. Now available on the UVA School of Law YouTube channel, the conference examines the evolution of forensic evidence and the role scientific research has played in criminal cases. Review the publicly available conference sessions to learn how the forensic science community can develop better forensic evidence, improve crime lab analysis, and present evidence more effectively in criminal cases. ln sessions facilitated by CSAFE team members, NIST researchers, the Innocence Project, and Houston Forensic Science Center, viewers will also discover more about the role of statistics in forensics, the crime lab, and the courtroom. A special symposium issue of the Virginia Journal of Criminal Law with published contributions from the conference is forthcoming. Visit the CSAFE blog (*https://forensicstats.org/2018/04/14/remembering-daubert-a-recap-of-the-csafe-symposium-on-forensics-statistics-and-law-at-uva/*) to learn more about the conference and for direct access to each conference session recording.

National Institute of Justice (NIJ) and NIJ-Sponsored Programs

National Institute of Justice Investing in Innovation for the Identification, Collection, and Analysis of Sexual Assult Evidence

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For nearly a decade, the Department of Justice Appropriations Act has annually included an appropriation of approximately $4 million (per fiscal year) for the Sexual Assault Forensic Exam (SAFE) Program. Under the SAFE program, the National Institute of Justice (NIJ), the primary funding agency for forensic science research in the US, supports grants and activities to provide training, technical assistance, education, equipment, and/or information (including research) relating to the identification, collection, preservation, analysis, and use of DNA samples and DNA evidence by medical and other personnel involved in treating victims of sexual assault.

Grants and activities funded through the SAFE program have continued to result in diverse and successful projects. Efforts include national best practices, training, technical assistance, and valuable research focused on improving and expediting the processing of sexual assault evidence. Each of these projects benefits NIJ's multidisciplinary stakeholders, including medical examiners, coroners, nurses, and victim service providers.

This article presents an overview of some of the currently open research and development (R&D) projects funded under the SAFE program. Doing so will demonstrate the breadth of research topics funded under SAFE and highlights how stakeholders at all levels — including academia, not-for-profit research firms, private companies, and law enforcement — are contributing novel insights into sexual assault and rape through both independent research and collaborative efforts.

Current Sexual Assault Forensic Evidence Best Practices and Capacity Enhancement Programs

Rape is one of four offenses falling within the definition of violent crime, which also includes murder, robbery, and aggravated assault. Data from the US Centers for Disease Control and Prevention (CDC) indicate that approximately 1 in 5 (18.3%) women and 1 in 71 (1.4%) men in the US will be raped in their lifetime. Among female victims, 42.4% will have been raped before 18 years of age; among male rape victims, 27.8% will have been raped at age 10 or younger [1]. To add to this, data from the Federal Bureau of Investigation (FBI)'s Uniform Crime Reporting Program show that in 2016 rape was reported to law enforcement at a rate of 41.2 per 100,000 individuals [2]. Rape also happens to be the most underreported crime, with data from the National Crime Victimization Survey indicating that approximately 77% of rapes or sexual assaults went unreported to law enforcement in 2016 [3].

Recent studies of untested rape kits, also known as sexual assault kits (SAKs), have demonstrated that many perpetrators are serial sex offenders. Using a sample of previously unsubmitted SAKs (i.e., those in police custody not submitted for testing), it was found that of those samples resulting in a DNA match (hit) through the Combined DNA Index System (CODIS; the federal DNA criminal database), 26.6% indicated a serial sexual assault [4]. Another study of sexual assaults with unsubmitted SAKs found that 56.3% were connected to serial sex offenses [5]. Because the majority of rapes are unreported, these values likely underestimate the prevalence of serial sexual assault.

Accordingly, anonymous self-report surveys indicate that as many as 78% of sexual assault perpetrators offend serially throughout their lifetime [6–8]. Furthermore, perpetrators of rape are often serial criminals. In a sample of arrest or conviction charges gathered from the 75 largest counties in the United States, it was found that 51% of those charged with rape had a prior conviction and 37% had a prior felony conviction, with 24% having been convicted of a nonviolent felony, and 13% having been convicted of a violent felony [9]. Given that many sexual assault perpetrators are serial offenders or are serial criminals, it is imperative that perpetrators be properly identified, tried, and convicted to end the trauma they continue to inflict on victims, reduce the costs they impose on society, and ensure safer communities in the future.

One way to properly and quickly identify potential rape offenders is through the timely and efficient processing of incoming SAKs. NIJ recently released the "*National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach*", delineating recommendations aimed at more effectively processing SAKs and providing justice to victims of sexual assault [10]. Several of those recommendations specifically address issues related to transparency and accountability for law enforcement agencies (LEAs) and forensic laboratories in the collection and testing of SAKs, which include:

- Receiving SAKs from a hospital or clinic within 3 business days of collection;
- Submitting SAKs for laboratory analysis within 7 business days of collection, or as specified by statute; and
- Conducting an inventory to determine the number, status, location, and descriptive information for all SAKs.

Other recommendations address laboratory processing of SAKs, which include:

- Considering the volume of sexual assault cases and using business process improvement tools to review their input/output;
- Incorporating robotics and/or automation at each step for the most efficient high throughput; and
- Considering the use of standardized templates, paperless systems, and specialized DNA interpretation software.

Although the above recommendations were only 6 out of 35 from the National Best Practices report — intended to demonstrate an ideal scenario for sexual assault case response — it must also be made clear that currently numerous sexual assault kits either sit in police custody (i.e., unsubmitted) or have been submitted to crime labs but may have not been tested in a timely manner. In an effort to address this challenge, for example, the Bureau of Justice Assistance (BJA)'s Sexual Assault Kit Initiative (SAKI) was designed to facilitate the processing of unsubmitted SAKs through a grant mechanism. To quote BJA (*https://www.bja.gov/ProgramDetails.aspx?Program_ID=117*),

> "Grant funding may be used to inventory the existing numbers of unsubmitted SAKs, test these kits, and assign designated personnel to pursue new investigative leads and prosecutions and to support victims throughout the investigation and prosecution process. Grants may also be used to develop evidence-tracking systems, train law enforcement on sexual assault investigations, conduct research on outcomes in sexual assault cases, and increase collection of offender DNA for CODIS upload purposes (in full adherence to the laws in the jurisdiction), that may lead to the identification of serious and serial sex offenders."

NIJ also provides significant grant funding for crime laboratory capacity enhancement and efficiency improvement, and for backlog reduction of DNA evidence acquired from sexual assaults and other crimes. NIJ's efforts to strengthen the capacity of forensic laboratories and reduce the overall backlogs of evidence have resulted in significant advances in the number of cases that can be processed. Since 2005, funding from NIJ's Capacity Enhancement and Backlog Reduction program has resulted in the analysis of evidence from over 860,000 cases, the upload of over 376,000 profiles to CODIS, and over 192,000 CODIS hits [11].

NIJ's SAFE Program Supports Critical R&D for Long-Term Solutions

While the efforts discussed above are focused on allocating resources to enhance crime laboratory capacity and efficiency, and help reduce and hopefully prevent future DNA backlogs, in order to move all types of cases forward and reduce violent crime, it is also critical to invest in R&D as part of a long-term solution. This is particularly true when it comes to ensuring that sexual assault evidence is collected and tested in ever more reliable, accurate, and efficient ways, which will not be accomplished without the continued development of innovative technologies and techniques. Undoubtedly, new and improved methods, along with technological advances, have allowed forensic scientists to reliably detect and analyze DNA from sexual assault evidence that would not have been possible otherwise.

NIJ's SAFE R&D efforts are critical to the methods and technological advancements developed across various stakeholder sectors and ultimately adopted by crime labs. Overall, R&D projects funded through the SAFE program have resulted in a diverse portfolio of projects that have helped advance the field's ability to analyze sexual assault evidence. For example, in 2013 NIJ funded Research Triangle International (RTI) to look at the variables affecting sexual assault kit processing efficiency in LEAs and crime labs. The research team at RTI, led by Dr. Kevin Strom, gathered data from 147 crime labs and 321 LEAs. Results recently obtained from this study indicate that staffing shortages, inefficient use of available resources, and insufficient resources are some of the primary factors contributing to LEAs and laboratories not processing SAKs as efficiently as possible.

Another group, led by Dr. Bruce McCord from Florida International University (Miami, FL), received a grant to develop a method that can rapidly identify and extract

male DNA from sperm cells when in the presence of female epithelial cells. This is critical to address because the differentiation and selective extraction of male DNA, when in the presence of female cells or DNA, can create a significant bottleneck in the DNA evidence-processing pipeline. McCord's research demonstrated the development of a novel sperm and epithelial cell extraction method from cotton swabs, using immunomagnetic capture pretreatment, pressure cycling treatment, and alkaline lysis [12,13]. This method demonstrated that a majority of male sperm sample concentration (up to 91%) can be extracted from the cotton swabs typically used to collect biological samples while leaving the female victim's DNA behind in the epithelial cells. Efforts from this project have led to industry collaborations aimed at developing an improved rape kit based on some of the above-mentioned techniques. Such a rape kit would help to significantly alleviate the bottleneck caused by identifying and differentiating DNA from mixed samples containing both male and female cells and DNA.

As can be seen from these examples, NIJ is supporting projects to develop solutions for quicker SAK processing as well as identifying key factors contributing to the SAK backlog. Ultimately, technological developments and lessons learned from both types of approaches will reduce the strain on LEAs and laboratories but, more important, they will bring resolution and justice to survivors of sexual assault. Currently, NIJ's SAFE program is funding 14 ongoing projects covering several forensic issues in sexual assault, including delineation of serial sexual assault patterns through DNA evidence, differentiation of menstrual blood from circulating blood, and the development of cell phone imaging systems for the rapid detection of sperm in sexual assault evidence samples.

SAFE R&D Projects Addressing Sexual Assault Forensic Evidence Challenges

The following descriptions of select projects demonstrates how NIJ is strategically helping to advance knowledge and justice with respect to treating victims of sexual assault.

Evidence, Sexual Assaults, and Case Outcomes: Understanding the Role of Sexual Assault Kits, Nonforensic Evidence, and Case Characteristics (Awardee: Urban Institute). The Urban Institute (Washington, DC) is conducting a prospective study to analyze the role that case characteristics and types of evidence gathered during medical forensic examinations play in achieving investigative goals and prosecutorial outcomes in cases of sexual assault. To do this, researchers plan to analyze close to 1,000 sexual assault cases from the New York State Police as well as several other LEAs across various New York counties. From these cases, they will review and categorize general case information, victim information, suspect information, and evidentiary information as well as case progress regarding investigation, arrest, charging, prosecution, and sentencing. Findings from this study will expand the knowledge of how sexual assault cases proceed through the criminal justice system and will be particularly useful to sexual assault nurse examiners, law enforcement officials, attorneys, and victim advocates. Furthermore, findings may help to create evidence-based policies aimed at more effectively prosecuting sexual assault cases.

Serial Sexual Assaults: A Longitudinal Examination of Offending Patterns Using DNA Evidence (Awardee: Michigan State University). Several studies, particularly those based on anonymous self-report, have indicated that the majority of sexual assault perpetrators are serial offenders [6–8]. In addition, approximately 77% of rapes go unreported [3], the majority of reported rapes are not adjudicated by the criminal justice system [14], and those that are prosecuted are disproportionately stranger-perpetrated [15]. In combination, these factors have led researchers to conclude that it is likely the confirmed incidence of serial sexual assault grossly underestimates the actual prevalence. To understand the patterns of serial perpetrators, a group at Michigan State University (East Lansing, MI) led by Dr. Rebecca Campbell is analyzing 7,287 previously untested SAKs from the Michigan State Police, the Detroit Police Department, and the Wayne County Prosecutor's Office. Results from these SAKs will be uploaded into CODIS to document the rate of sexual assaults, especially those involving serial rapes. Through the examination of records, Dr. Campbell's group will also be able to determine how serial sexual assault varies by stranger vs. nonstranger sexual assault.

Development of Surface-Enhanced Raman Spectroscopy (SERS)-Active Forensic Evidence Swabs for Rapid, Nondestructive Confirmatory Serological Screening and Short Tandem Repeat (STR) Typing of Human Bodily Fluids (Awardee: Western Carolina University). Tests traditionally used to screen swabs collected during medical forensic exams for human body fluids are time consuming, expensive, only reliable for one body fluid, and can destroy the sample. Recent research, however, has shown that certain nondestructive spectroscopic methods may have improved detection limits over those typically used in crime laboratories and

may be used as all-inclusive tests for bodily fluids. For example, in Raman spectroscopy (typically categorized as nondestructive), laser light is scattered by a sample into frequencies that are characteristic of the chemical composition of the analyte. Because only a small fraction of the light interacts with and is scattered by the analyte, the Raman signal is relatively weak. The use of surface-enhanced Raman spectroscopy (SERS), where the analyte is placed on or near a nanostructured metal surface, greatly enhances the Raman signal and may therefore decrease the detection limit over conventional methods. To determine whether it is feasible to use SERS as a method for forensic analysis, researchers at Western Carolina University (Cullowhee, NC), led by Dr. David D. Evanoff, are working on developing SERS-active forensic evidence swabs by attaching silver nanoparticles to commercially available swabs. The development of such swabs could allow for the rapid screening of multiple biological fluids. This could significantly decrease time and costs spent on analyzing forensic samples if used in conjunction with portable Raman instruments.

A Rotational Platform-Driven Microdevice for Differential Separation, Purification, and Amplification of Sexual Assault Forensic Samples (Awardee: Virginia Commonwealth University). There is a need to reduce the workload and costs involved in processing SAK DNA evidence. Such work falls into two domains: Research seeking to develop completely new techniques for kit processing; and methods or new technologies seeking to improve specific portions of the total workflow. While an all-in-one device may eventually replace current workflow processes and equipment, we are likely years away from such a technological feat. In the meantime, development of new techniques or devices to improve portions of the workflow are necessary to help reduce the SAK backlog and increase the capacity of crime labs. To address this need, researchers at Virginia Commonwealth University (Richmond, VA), led by Dr. Tracey Dawson Cruz, are developing a microchip-based assay that would significantly reduce the upstream work associated with SAK DNA sample processing. The resulting device and associated methods would replace the following time-consuming steps: sample preparation, sperm and nonsperm cell separation, DNA purification, and multiplex short tandem repeat (STR) polymerase chain reaction (PCR) amplification. Specifically, the microdevice would be able to accomplish these steps using samples attained from swabs, using two recently developed on-chip modules (DNA purification and PCR) and a rotational platform for microfluidic control.

Bioinformatic Analysis of Big Proteomic Data: A New Forensic Tool to Identify Menstrual Blood and Body Fluid Mixtures (Awardee: NYC Office of Chief Medical Examiner). Differentiating menstrual blood from venous blood is important during sexual assault forensic investigations in which vaginal blood has been collected, as venous blood can be indicative of trauma. Whether present at a crime scene or acquired through a SAK, differentiating the two has been a historically problematic issue for the forensic community. While other commonly tested bodily fluids, such as semen and saliva, have unique proteins that can be used to easily differentiate them from each other, menstrual blood contains a minute amount of uterine endometrial proteins mixed in with a large volume of typical blood proteins. Through a previous NIJ award, the research team at the New York City Office of Chief Medical Examiner (NYC OCME) was able to examine the menstrual and venous blood proteomes of 45 women. Using combinatorial peptide ligand chromatography (CPLC), NYC OCME was able to selectively enrich low-abundance proteins present in menstrual blood, effectively resulting in relatively equal quantities of initially rare and low-abundance proteins after separating them from other blood components (i.e., elution). They were able to identify five menstrual blood-specific markers and four additional menstrual blood-enriched markers using chemical analytical techniques. The research team also determined that the most consistent menstrual blood sample was obtained on the second day of menses.

The NYC OCME research team aims to sample the menstrual and venous blood of 100 women on the second day of menses. Furthermore, they plan to take advantage of a more powerful chemical analysis hardware to potentially identify additional proteomic markers in samples that have been run through CLPC. Ultimately, however, the goal is to use the identified markers to develop a highly accurate, bioinformatics-based predictive model to differentiate non-CLPC menstrual blood, as CLPC is time consuming and expensive.

A Confirmatory Test for Sperm in Sexual Assault Samples Using a Microfluidic-Integrated Cell Phone Imaging System (Awardee: Stanford University). Testing for and identifying sperm in a forensic sample is a crucial part of producing a DNA profile in order to identify a perpetrator. The only gold-standard confirmatory test for sperm is to use a microscope to visualize and identify sperm within an acquired sample. The setup and procedures for a microscope-based system, however, are fairly complex and do not lend themselves to use at a

crime scene. Consequently, technological limitations have precluded the development of a portable forensic system that can provide rapid confirmatory test results for sperm. Such a test, for example, would be particularly useful in identifying the most probative SAK samples. Given the increasing use of microchip-based systems in biological applications and miniaturization of hefty computing power, Dr. Utkan Demirci's team at Stanford University (Stanford, CA) is proposing the development of a cell phone-based imaging system coupled to a microchip enzyme-linked immunosorbent assay (ELISA) for onsite forensic applications, the latter of which has demonstrated high efficiency and specificity for sperm from mixed-cell populations. To validate the ability of the microfluidic chips to capture sperm, the research team collaborated with the Broward Sheriff's Office Forensic Laboratory (Fort Lauderdale, FL) to acquire simulated forensic samples prepared by forensic lab personnel. To accurately simulate samples potentially acquired from a crime scene, all of the collected samples were dried and kept at room temperature. In continuing to market the resulting technology, Dr. Demirci's team will commercialize the integrated platform for forensic screening applications.

Moving Beyond the Backlog: Innovation in Sexual Assault Forensic Evidence Processing

An ongoing and controversial issue within the forensic community is the backlog of sexual assault forensic evidence. This backlog includes non-DNA and DNA forensic evidence collected as part of a SAK, which can be categorized as unsubmitted or as meeting a formalized definition of backlogged (e.g., submitted to a crime lab but untested after 30 days). As NIJ continues to provide funding to aid state and local crime labs and LEAs in reducing unsubmitted and backlogged sexual assault evidence, it is important to remember that this is only part of the solution to prosecuting offenders, preventing future incidents of rape and sexual assault, and providing justice for victims. To truly propel the field of forensic evidence processing forward, it is crucial to support R&D efforts that will pave the way for novel and innovative methods. Through the SAFE program, NIJ is able to provide stakeholders funding and support to address SAK-related issues.

This article has summarized several ongoing NIJ-supported efforts to improve the accuracy and speed with which SAKs are processed, ultimately resulting in speedier offender identifications and backlog reduction. For example, NIJ awards are being used to understand the root causes of SAK backlogs through social science-based methods and to facilitate the development of low-cost and/or easily deployable technologies capable of user-friendly processing and rapid results. Such R&D not only aids LEAs in quickly identifying offenders but also sets up crime labs and LEAs for a sustainable future devoid of backlogs. Altogether, a two-pronged approach consisting of funding directed at both backlog reduction and R&D is necessary to address current SAK-related issues.

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Forensic Technology Center of Excellence: Moving Knowledge from Research to Practice — 2018 Midyear Update —

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RTI International (RTI) and its academic- and community-based consortium of partnerships, including its Forensic Science Education Programs Accreditation Commission partners, work to meet all tasks and objectives put forward under the National Institute of Justice (NIJ) Cooperative Agreement No. 2016-MU-BX-K110. These efforts include determining technology needs; developing technology program plans to address those needs; designing solutions; demonstrating, testing, evaluating, and adopting potential solutions into practice; creating and updating technology guidelines; and building capacity and conducting outreach. This report provides a midyear update to the forensic community on Forensic Technology Center of Excellence (FTCoE) activities and deliverables. Access all deliverables at *www.forensicCOE.org*.

Meetings and Symposia

SOFT-TIAFT Joint Meeting. The Society of Forensic Toxicologists (SOFT) and The International Association of Forensic Toxicologists (TIAFT) held a joint meeting January 6–12, 2018, in Boca Raton, FL. More than 1,200 forensic professionals gathered from around the world to discuss the latest research, technologies, and policies related to forensic toxicology. At the meeting, the FTCoE led two workshops, gave two oral presentations and two poster presentations, facilitated a discussion session at an evening forum, and led opening ceremonies. Additionally, the FTCoE disseminated a flyer detailing recent and upcoming FTCoE activities of interest for forensic toxicologists and other meeting attendees.

Impression, Pattern, and Trace Evidence Symposium (IPTES). The FTCoE hosted IPTES January 22–25 in Arlington, VA. This symposium brought together more than 600 practitioners and researchers to enhance information-sharing and promote collaboration among the law enforcement community, the legal community, and the impression, pattern, and trace evidence community. At the beginning of the week, participants attended 13 interactive workshops spanning several topics — including probabilities and likelihood ratios in pattern evidence, firearm and toolmark examinations, and applied polarized light microscopy. For the remainder of the week, participants engaged in a variety of content, including keynote addresses, panel discussions, and poster and scientific sessions. The FTCoE sent out daily updates to its 24,000 newsletter subscribers; these updates included symposium highlights, a photo of the day, and details about upcoming IPTES sessions. Additionally, short in-brief reports about the following workshops were compiled to summarize the purpose of the individual workshops, the lecture material, and the exercises completed. Visit *www.forensiccoe.org/workshop/18-iptes/* to access presentation archivals and in-brief reports.

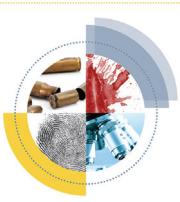

Figure 1. Impression, Pattern, and Trace Evidence Symposium logo.

- **Applied Polarized Light Microscopy for Trace Evidence Examiners.** This workshop introduced attendees to the theory and applications of polarized light microscopy by utilizing a combination of lecture and laboratory activities. Topics included proper microscope setup, refractive index measurement, basic optical crystallography, retardation and birefringence, extinction characteristics, and compensators.
- **Forensic Wood Identification.** This workshop provided an overview of forensic wood identification to scientists who had little or no knowledge of the topic; the workshop also included lectures on the macroscopic and microscopic features that are useful for classification, sample preparation techniques, and hands-on exercises.
- **Statistical Interpretation Software for Trace Evidence Examiners (FRStat).** The Defense Forensic Science Center developed FRStat to provide a statistical estimate of the strength of evidence to be used in conjunction with the examiner's own conclusion. This workshop covered basic statistical concepts, interpretation and reporting of FRStat results, limitations, considerations for use, and implementation suggestions.

Medicolegal Death Investigation (MDI) Stakeholders' Meeting. The FTCoE hosted the MDI Stakeholders' Meeting February 5–6 in Washington, DC. This meeting provided the opportunity for an open discussion about needs and challenges in the MDI practitioner community. More than 50 MDI professionals, representing 40 agencies/organizations, joined together to gather information and feedback on NIJ programs that are specifically dedicated to medical examiner and coroner offices and their laboratory support services.

Federal Forensic Science Research Programs Stakeholders' Meeting. The FTCoE hosted the Federal Forensic Science Research Programs Stakeholders' Meeting on

February 12 in Washington, DC. This meeting brought together 68 forensic professionals across 29 organizations to discuss forensic science research programs. The purposes of this stakeholders' meeting were to (a) provide an opportunity for federal agencies that either conduct or support forensic science research to understand the various efforts taking place at other federal agencies; (b) facilitate greater understanding of the various forensic science research efforts to mitigate duplication; (c) create greater understanding of the vast efforts in forensic science research and development (R&D) and identify potential opportunities for federal agencies to partner and leverage each other's strengths; and (d) coordinate all federal forensic science R&D efforts and possibly begin an annual exchange of information.

AAFS 70th Annual Meeting. The American Academy of Forensic Sciences (AAFS) held its 70th annual meeting February 19–24 in Seattle, WA. Approximately 5,000 forensic professionals gathered from around the world to discuss the latest research, technologies, and policies in their fields. The meeting focused on research, diversity, and communication. The FTCoE contributed in a variety of ways, including booth operation, outreach and dissemination, and participation in a breakfast seminar panel. The seminar titled, "The Making of an Opioid Crisis in America: Why Research, Policy, and Practice Matter", was part of an ongoing joint effort between the FTCoE and AAFS Synthetic Opioids Ad Hoc Committee to heighten awareness of the opioid crisis in the United States. Additionally, the FTCoE disseminated resources to conference attendees — including a flyer highlighting its mission and accomplishments as well as a collection of postcards detailing FTCoE activities.

NIJ Forensic Science R&D Symposium. The FTCoE hosted the annual NIJ Forensic Science R&D Symposium on February 20 in conjunction with the AAFS meeting in Seattle, WA. This symposium brought together hundreds of forensic professionals (in person and online) to learn about NIJ-supported research across a variety of forensic science disciplines. The morning sessions covered forensic anthropology as well as controlled substances and toxicology; the afternoon sessions covered trace microbiome and forensic biology/DNA. Presentation archivals are available at *www.forensicCOE.org*.

Figure 2. NIJ Forensic Science R&D Symposium logo.

RTI Policing Symposium. FTCoE representatives attended the RTI Policing Symposium on February 23 in Research Triangle Park, NC. This symposium brought together more than 100 participants from agencies across the Carolinas to discuss challenges and collaborate around topics focused on victim-centered responses to sexual assault and domestic violence. North Carolina Attorney General Josh Stein welcomed symposium attendees and gave a keynote address that highlighted policies and programs his office is pursuing to help fight human trafficking, sexual assault, and intimate partner violence. Themes throughout the day included the importance of a multidisciplinary approach and offender focus, as well as considerations for vulnerable populations. The symposium concluded with information about how communities can use surveys to attain a comprehensive understanding of crime, perceived community safety, and law enforcement relations.

Evidence Management Steering Committee Meeting. The NIJ and the National Institute of Standards and Technology (NIST) kicked off their joint evidence management project with the project's first Executive Steering Committee meeting March 6–8 in Gaithersburg, MD. This meeting brought together stakeholders to discuss best practices for evidence management for the purpose of strengthening the US criminal justice system. The Executive Steering Committee will identify best practices for evidence management, revise current standards to reflect those best practices, and facilitate community awareness of the many challenges and solutions related to evidence management. Two FTCoE scientists participated in the meeting as members of the survey subcommittee. This subcommittee is tasked with the development, dissemination, and analysis of a survey to gain insight into current evidence management practices throughout the US.

Whiskey in the Courtroom Symposium. Duke University Law School hosted the fourth annual Whiskey in the Courtroom Symposium on March 9 in Durham, NC. This symposium focused on evolving trends in forensic science; this year's theme was Fires, Liars, and More. Presentations focused on fire investigations, coerced confessions, and case studies. Three FTCoE scientists attended the symposium to present posters and participate in a panel discussion. The first poster highlighted black box studies and error rates. The second poster highlighted noble cause and the need for forensic scientists to receive leadership training.

Human Factors Sourcebook Working Group Meeting. The FTCoE hosted a three-day working group meeting March 14–16 at RTI International in Research Triangle

Park, NC, in support of the Human Factors in Forensic Science Sourcebook project. The goal of this sourcebook is to find areas in which human factors knowledge can be used to improve laboratory practice and to bridge the gap between existing knowledge and operational implementation.

National SAKI Grantees Meeting. The Bureau of Justice Assistance (BJA)'s Sexual Assault Kit Initiative Training and Technical Assistance (SAKI TTA) program hosted the third annual National SAKI Grantees meeting March 27–28 in Arlington, VA. This event provided all SAKI and New York County District Attorney's Office (DANY) grantees the opportunity to share information with — and derive policies from — their peers for sustainable, national sexual assault reform. The FTCoE presented on sexual assault initiatives and held office hours for attendees wanting more information about the FTCoE.

Western States Joint Conference of the International Association for Identification (IAI) Annual Training Seminar. The first-ever Western States Joint Conference of the IAI was held April 30–May 4 in Las Vegas, NV. The Western States Joint Conference of the IAI is the 2018 training seminar for the California, Pacific Northwest, Rocky Mountain, Utah, Nevada, and Arizona divisions of the IAI. The FTCoE presented two talks and one workshop at the conference. The two talks were titled "Understanding and Calculating Error Rates in Pattern Evidence" and "Twice Bitten — The Lecture! Latent Print Perspectives on the PCAST Report." The workshop was titled, "Latent Print Testimony: How to be Transparent Without Feeling Naked."

Success Stories

Success stories highlight awardees' impactful outcomes obtained via their NIJ-supported research projects. The FTCoE recently published the following stories, which are available at *www.forensiccoe.org/category/nij-success-stories/.*

NIJ and Synercon Technologies: Improving the Reliability of Forensic Data from Vehicle Data Records. Dr. Jeremy Daily and colleagues at the University of Tulsa (Tulsa, OK) have developed and commercialized new technologies that provide the ability to retrieve forensically sound data from event data recorders. These technologies were developed under the NIJ award 2010-DN-BX-K215 and enable law enforcement to acquire digital forensic data from commercial vehicles faster and more reliably than older technologies.

NIJ and Florida International University: Forensic Epigenetics — Markers for the Identification of Body Fluids. With NIJ's support (award number 2012-DN-BX-K018), Dr. Bruce McCord's team at Florida International University (MIami, FL) discovered that certain epigenetic markers display distinct methylation patterns, which can be used to identify body fluids (e.g., semen, blood, vaginal fluid) and epithelial cells (e.g., buccal, skin).

NIJ and JENSEN HUGHES: Advancing the Forensic Analysis of Ignitable Liquid Fuel Fires. With NIJ's support (award number 2008-DN-BX-K168), Dr. Daniel Gottuk of JENSEN HUGHES (Baltimore, MD) developed a reliable and accurate method of obtaining calcination depth surveys with a portable, handheld measuring tool developed for improved fire pattern analysis.

NIJ and Florida International University: NIST's Dog and Sensor Subcommittee Builds on Achievements by SWGDOG. This success story outlines the impact that NIJ funding (award number 2005-IJ-CX-K031) played in identifying research priorities and the development of best practice documents with regard to dogs and orthogonal detectors.

NIJ and the American Registry of Pathology: Maximizing the Use of DNA in Identifying Remains and Aiding Missing Persons Casework. Dr. Jodi Irwin, Dr. Rebecca Just, and Dr. Walther Parson — with the support of NIJ (award number 2011-MU-MU-K402) — developed a forensic-quality mitochondrial genome (mtGenome) population database with more than 500 complete mtGenomes spanning three US population groups.

NIJ and Multi-Institute Academic Team: Establishing a "Microbial Clock" to Improve Time-of-Death Prediction. This success story details the research of Dr. Rob Knight and colleagues, who — through NIJ funding (award number2011-DN-BX-K533) — developed a postmortem interval (PMI) estimation method based on the composition of microbial communities present on the body and within close-proximity soil samples.

Reports

Landscape Report on Alternative Light Sources. This landscape report on alternative light sources (ALS) offers decision makers and potential end users issues to consider related to implementation and usage examples that illustrate the successful adoption of a technology. Additionally, this report addresses advances in ALS

technology for impression and biological forensic evidence and pattern injury detection. Novel technologies that have recently arisen include light sources with more and tighter wavelengths, infrared light sources for blood detection, handheld laser-emitting diode lights, and advances in bandpass filter technologies.

Landscape Study of Field Portable Devices for Presumptive Drug Testing. The goal of this report is to inform the forensic community about the current landscape of field portable devices and techniques used for presumptive drug testing. This report also contains a discussion of the benefits, limitations, and implementation considerations for various technologies — including mass spectrometry (MS), ion mobility spectrometry (IMS), portable Raman spectroscopy, infrared spectroscopy (IR), and color-based testing techniques. This report illustrates successful adoption of these technologies in a field setting and identifies up-and-coming technologies that could impact presumptive drug testing in the future.

Webinars and Online Resources

Webinar: A Close Look at 3D Microscopy for Firearms Identification. The field of firearms identification is undergoing a major change in technology and capability with the introduction of optical topography into forensic laboratory practice. Optical topography provides a three-dimensional (3D) view of the surface of a bullet or cartridge case at resolutions that capture the full range of subclass and individual characteristics. This webinar informed forensic professionals about the application of optical topography in the crime laboratory; provided a comparison of available instruments; discussed barriers to broader adoption of optical, topography-based solutions; provided practical and technical considerations faced by crime laboratory practitioners who may plan to adopt optical topography in their laboratories; and provided an overview of ongoing developments of the technology and associated standards.

Webinar: Transition to Impact — Bringing Research to Practice. Enabling great research to have impact in the forensics community requires transitioning knowledge from the laboratory to the market. Technology and knowledge transition are integral parts of creating impact from scientific research; researchers want their findings to improve the practice of forensic science and benefit end users across many different criminal justice system domains. This webinar provided guidance to attendees about what transition means for their projects and highlighted key factors that should be considered to ensure future success.

Webinar: Computerized Reconstruction of Fragmentary Skeletal Remains. In forensic contexts, a biological profile constructed from unidentified skeletal remains assists in the search for missing persons; additionally, this profile is necessary for sorting commingled remains and identifying victims in mass graves. The reliability of information extracted from the skeletal remains is highly dependent on the degree of integrity and preservation of the specimens. In cases of partial bones, the missing elements may limit the amount of information that can be derived from the skeleton. Commingling further complicates the task because not all fragments are easily reconstructed or designated to a single individual. This webinar introduced attendees to "Fragmento", a newly developed software tool that allows users to sort and assemble skeletal fragmentary remains and reconstruct the full bone and biological profile.

Webinar Series: Forensic DNA — The Beginning of the SNP Era. The field of forensics is constantly evolving. Although short tandem repeats (STRs) are currently used in all forensic DNA laboratories for human identification, single nucleotide polymorphisms (SNPs) have emerged as new markers of interest. These new markers present several benefits, including the ability to analyze smaller DNA fragments (and the ancestral and phenotypic information they may carry) as well as the ability to distinguish STRs of the same size. New technologies for genotyping SNPs have been developed in recent years, and these technologies will continue to advance for many years to come.

This webinar series explored the use of SNPs for forensic applications and discussed recent advances in the field. The FTCoE collaborated with George Washington University (Washington, DC), alongside Dr. Daniele Podini, to deliver this webinar series to a total of 753 attendees.

Webinar Series: Opioid Crisis — A Public Health Enemy. Rates of opioid use and misuse have reached epidemic proportions and are affecting many aspects of both criminal justice and forensic sciences programs. Opioid addiction is the driving force behind increased use. In 2015, nearly 3 million Americans reported a substance use disorder related to prescription pain relievers or heroin, fueling a steady increase in fatalities to an estimated 91 US deaths daily. Far from slowing, these rates are doubling, quadrupling, or increasing at even higher numbers in some areas. Law enforcement, medical professionals, laboratories, and legal agencies are facing unmanageable caseloads, budget shortfalls, and other challenges in achieving safety, analytical preparedness, and basic education/training. Reliable surveillance and intelligence are needed more than ever to combat the

fast-paced life cycles of emerging drugs. The legislative quagmire is just as burdensome, as policy change cannot happen without data to support it.

This webinar series offered a multifaceted perspective on how diverse criminal justice disciplines are addressing these challenges; sharing their knowledge; and advancing science, technology, and law. Addressing the impacts of the opioid crisis on the criminal justice system requires better reporting, surveillance, research, technology, and policies. A total of 2,914 attendees from across the world joined 18 subject matter experts to discuss the opioid crisis in the US.

Webinar Series: DNA Kinship Testing. DNA kinship testing is a proposed method within the Department of Homeland Security (DHS) for confirming the presence of a biological relationship between two individuals for immigration purposes, preventing human trafficking, and identifying mass disaster victims. This webinar series discussed the findings from research conducted at GWU to offer improvements on kinship testing methodologies. This research was supported by the DHS Science and Technology (S&T) Directorate. To develop this webinar series, the FTCoE collaborated with Christopher Miles of DHS S&T, Dr. Amanda Sozer of SNA International, and Drs. Daniele Podini and Moses Schanfield of GWU. The FTCoE delivered the entire series during March to a total of 464 attendees.

Leadership Series. The FTCoE, in partnership with the American Society of Crime Laboratory Directors (ASCLD), developed 12 online learning modules that introduce leadership concepts to forensic scientists at no cost. Highly functioning leaders are essential to operational excellence, process and analytical reliability, workforce competency, efficiency, technology and best practice implementation, and overall quality in the laboratory. This series can be used in conjunction with the ASCLD leadership academy or National Forensic Science Academy, or as part of standalone efforts by individual laboratories. This knowledge also supports laboratory accreditation and professional certification. The content includes discussions about innovation, standards, ethics, and organizational excellence that are critical to FTCoE's mission.

Just Science Podcast

The Center for Forensic Sciences at RTI produces a podcast series, funded in part by the FTCoE and hosted by Dr. John Morgan, called *Just Science*. This podcast series represents a concerted effort involving community, industry, and discipline leaders to disseminate research and real-world practice to a wide audience — sparking conversations and innovations within the field. *Just Science* explores new technologies and systems that provide more efficient ways of delivering quantitative results and the human factors that go into producing solid data. Since its launch in May 2017, the FTCoE has hosted a total of 39 episodes, 3 complete seasons, and 2 special-release seasons. In the current season of *Just Science*, titled "Drugs," Dr. Morgan discusses a variety of topics with subject matter experts, including the legalization of marijuana, the opioid epidemic, and vaping research. *Just Science* can be found on iTunes, Google Play, Stitcher, and SoundCloud.

Figure 3. *Just Science* Podcast logo.

Sexual Assault Initiatives

The Multidisciplinary Sexual Assault Glossary. The FTCoE, in collaboration with the Center for Forensic Nursing Excellence International (CFNEI; Henderson, NV), produced a sexual assault online glossary for medical, law enforcement, and legal professionals. Effective communication among interdisciplinary professionals is essential. To develop this glossary, CFNEI engaged with multidisciplinary subject matter experts who contributed to developing the terms list, writing associated definitions, and reviewing the multidisciplinary terminology/definitions. A consensus model was used to clarify ambiguous terms or terms with opposing definitions found in the literature and/or reference materials. This project served to create a resource that can be used to help bridge language-related communication gaps and potential miscommunications associated with discipline-specific terminology. This glossary was initially developed in 2016 under award number 2011-DN-BX-K564, which led to more than 970 terms being uploaded to the searchable glossary. Under the current award, additional terms related to sexual violence and exploitation were added and the glossary now hosts 3,586 unique terms. The glossary has been visited 8,402 times from January 1 through February 28 from users around the world — including US, Indonesia, India, UK, and Germany. Approximately 59% of users are from organic searches, 33% from direct searches, 7% from referral, and the remainder from social channels. Access the glossary at *www.cfnei.com* and *www.forensiccoe.org/sexual assault*.

TEITELBAUM'S COLUMN ON FORENSIC SCIENCE — HISTORICAL PERSPECTIVE —

Luke May and the Revelare International Secret Service

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Although US newspapers of the 1920s through the 1940s often referred to Luke May as the "Sherlock Holmes of America", his name is virtually unknown among today's criminalists and forensic scientists. And while other criminologists and detectives of his day were also celebrated in the media — William Burns, Edward Oscar Heinrich, and Ellis Parker, to name a few — perhaps none of them fit the moniker better than May. Books detailing the history of forensic science often mention him, usually in just a sentence of two, and usually in conjunction with pioneering the field of toolmark striation analysis. But May was one of the very first practitioners of scientific criminal investigation in the United States, and the methods and techniques he developed greatly influenced succeeding generations of criminologists.

Luke May was born in 1886 in Nebraska, then moved to Salt Lake City with his family as a young boy [1]. He gravitated to books about criminal behavior, chemistry, and fingerprints, and perhaps the most influential book of his youth, and his adult life, was the famous *Criminal Investigation*, by Hans Gross, which May had translated from German to English by a friend. By age 16, May was a familiar figure around the local police stations and courts, soaking up all he could about how crimes were investigated and prosecuted.

He started working as a private detective around age 17 and soon opened up his own agency, which he called the Revelare International Secret Service. Like Sherlock Holmes, May's detective agency combined the fields of criminal psychology, physical evidence analysis, and crime scene investigation under one roof. Crime labs did not yet exist in the United States, and, since police and government agencies did not yet have these services, detectives like May did much of their work for sheriffs, police departments, prosecutors, and state and federal law enforcement agencies.

In 1919, seeking more work and a larger city, May relocated the Revelare agency to Seattle, WA, and almost immediately was called in to investigate the state's highest-profile crimes.

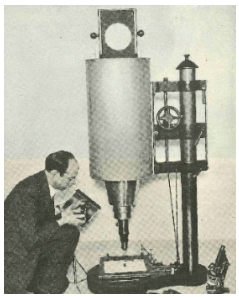

Figure 1. Revelaroscope.

Within months of his moving to Seattle, the Centralia Massacre took place in the logging town of Centralia, WA. The "Wobblies", the nickname for a radical labor union, opened fire on unarmed veterans who were marching in a parade, and this case became Luke May's first major investigation in his new state.

He was called in for the Bremerton Massacre (there seemed to be a lot of massacres in Washington back then), where six people were inexplicably gunned down in a house. May was instrumental in finding the killer and the motive.

One of the most sensational crimes in 1920s Seattle involved Jim Mahoney, a petty thief who had served some time in jail [2]. When he was released, he met, courted, and eventually married Kate Mooers. He was 36 and she was 68. He returned from their honeymoon alone and, strangely enough, people started to wonder where his rich wife was — especially when he produced signed papers where she gave him control of her estate. Luke May determined that the signatures on the papers were forged (signed by the woman's sister, who was in league with Mahoney), and he helped in the investigation to locate the missing woman. Unfortunately for Mrs. Mahoney, the investigation led to Lake Union, where Jim Mahoney had been seen rowing a rowboat with a trunk in it. It didn't end well for Mrs. Mahoney, or for Mr. Mahoney, who was hanged following a short trial.

The decades of the '20s and '30s were the pinnacle of Luke May's professional successes. He had 50 operatives working for him throughout the city and state, and he set up a state-of-the art crime laboratory that contained a number of instruments of his own design.

More than any other tool, the microscope was the most important instrument in May's laboratory, and he often discussed the key role that the microscope played in his investigations [3]. One of May's most unique inventions was a giant comparison microscope that he called the *Revelaroscope*. It was over 7 feet tall and weighed more than half a ton, and he found it indispensable in his work. Among its features was the ability to project an item's image onto a 10-inch screen, then photograph that image with a built-in camera so that it could be used in courtroom presentations.

He helped start a school called the *Institute of Scientific Criminology*, which was probably the very first formal

school of criminology in the US [4]. The purpose of the school was to promote "teaching scientific criminal investigation, practical methods of detection, systems of identification, and laws of evidence and procedure". He renamed his private agency the **Scientific Detective Laboratories**, and the advanced students at the crime school were allowed to study directly under him in his laboratory.

Figure 2. Flyer advertising May's Institute of Scientific Criminology.

In the late 1920s, following the St. Valentine's Day Massacre in Chicago, the city decided that it needed a crime lab. May was asked to come to Chicago and help design the new lab, which was called the *Scientific Crime Detection Laboratory***.** The first director of this new laboratory was firearms expert Calvin Goddard. Some historians believe that the first US crime lab was started in Los Angeles in 1923, but just as many feel that the Chicago lab, the first full-service forensic crime lab that encompassed all of the different analytical disciplines, deserves the title of first US crime lab.

In 1933, the mayor of Seattle asked May to serve as chief of detectives in Seattle, which he did without pay, mainly because the city council had eliminated the budget for that position. During May's tenure, the number of successfully solved criminal investigations in the department skyrocketed. After he left that position, the mayor gave him the official title of "Consulting Criminologist" for the city of Seattle.

May was also a prolific author. In 1933, he published *Scientific Murder Investigation*, a manual that outlined, step-by-step, the procedure for methodically building a criminal case. Some consider this manual to be the first criminal investigation book ever published in the United States. He also wrote monographs on fingerprint detection and knife identification, as well as a full-length book called *Crime's Nemesis*, a collection of accounts of his most interesting criminal cases. He also provided case material for *True Detective Mysteries*, which was a hugely popular magazine in its day. There was a sensationalistic aspect to the stories, but they were also incredibly detailed accounts of true criminal investigations.

In 1930, one of May's cases led to a state court admitting toolmark evidence, one of the first times in the United States that this type of evidence was allowed [5]. A schoolgirl in Roy, WA, had been brutally assaulted, but the only evidence the local sheriff's office could produce were saplings that had been cut with a knife. The saplings had been used to shield the predator from view while he had waited for the girl. One of the eventual suspects had a pocketknife, which May subjected to intense scrutiny and a variety of tests. He noticed that there was fir pitch on one blade. Under a microscope, he observed that there were irregularities on the edge of the blade that couldn't be seen with the naked eye. Finally, he built a device that allowed the blade to cut through sample saplings at an angle consistent with the suspect's right arm. The evidence he accumulated, using the microphotographs that he produced, proved to the court that the man being accused of the crime was the right man. Part of the court's decision reads:

> *Courts are no longer skeptical that by the aid of scientific appliances, the identity of a person may be established by fingerprints. There is no difference in principle in the utilization of the photomicrograph to determine that the same tool that made one impression is the same instrument that made another impression. The edge on one blade differs as greatly from the edge on another blade as do the lines on one human hand differ from the lines on another. This is a progressive age. The scientific means afforded should be used to apprehend the Criminal.*

In general, the 1930s brought about technological advances in science that dramatically changed the way that criminal investigations were conducted and provided new types of evidence that changed the way that criminals were tried and prosecuted. Luke May was absolutely a leading proponent of these scientific methods and he did so for over four decades.

And while May based much of his career on the pioneering efforts of Locard, Bertillon, Lombroso, Vidocq, Gross, and others, he also paid special tribute to Sherlock Holmes, saying:

> *Without disparaging progressive police officers of all nations, I believe that the writings of Conan Doyle have done more than any other one thing to stimulate active interest in the scientific and analytical investigation of crime.*

By the time that May died in 1965, however, he had long since faded from public service. Law enforcement agencies had set up their own crime labs years earlier and private criminologists were rarely needed anymore. But Luke May deserves wider recognition for pioneering scientific methodology in the service of criminal investigation in the United States.

References

1. Coe LM: One time Nebraskan is famous Seattle criminologist; *Nebraska State Journal* p 25; May 26, 1935.
2. Armstrong H: Accused man nervous as trial opens; *The Seattle Star* p 1; September 22, 1921.
3. Arnett S: Crime can't beat the microscope; *Seattle Sunday Times* p 5; January 25, 1931.
4. Fultz H: Behind the scenes with a great criminologist; *True Detective Mysteries* pp 58–61; 112–116; April 1935.
5. May L: *Crime's Nemesis*; Macmillan: New York, NY; pp 39–54; 1936.

NEW BOOKS AND BOOK REVIEW

New Forensic Science Books

A Laboratory Manual for Forensic Anthropology
A. Christensen, N. Passalacqua
Academic Press/Elsevier: Waltham, MA, US; 2018

***Ballistics: Theory and Design of Guns and Ammunition*, 3rd ed**
D. E. Carlucci, S. S. Jacobson
CRC Press: Boca Raton, FL, US; 2018

***Crime Scene Investigation Laboratory Manual*, 2nd ed**
M. Miller
Academic Press/Elsevier: Waltham, MA, US; 2018

Cybercrime and Digital Forensics: An Introduction
T. J. Holt, A. M. Bossler, K. C. Seigfried-Spellar
CRC Press (Routledge): Boca Raton, FL, US; 2017

Digital and Document Examination
Max Houck, Ed
Academic Press/Elsevier: Waltham, MA, US; 2018

Digital Forensics
A. Årnes, Ed
Wiley-Blackwell: Somerset, NJ, US; 2017

Digital Forensics and Investigations: People, Process, and Technologies to Defend the Enterprise
J. Sachowski
CRC Press: Boca Raton, FL, US; 2018

Ethics and Professionalism in Forensic Anthropology
N. Passalacqua, M. A. Pilloud
Academic Press/Elsevier: Waltham, MA, US; 2018

***Ethics and the Practice of Forensic Science*, 2nd ed**
R. T. Bowen
CRC Press: Boca Raton, FL, US; 2017

Ethics in Forensic Psychology Practice
R. K. Otto, A. M. Goldstein, K. Heilbrun
Wiley-Blackwell: Somerset, NJ, US; 2017

Food Forensics and Toxicology
T. A. M. Msagati
Wiley-Blackwell: Somerset, NJ, US; 2017
(only *e-book and o-book*)

Forensic Digital Image Processing: Optimization of Impression Evidence
B. Dalrymple, J. Smith
CRC Press: Boca Raton, FL, US; 2018

Forensic Evidence Management: From the CrimeScene to the Courtroom
A. Mozayani, C. Parish-Fisher, Eds
CRC Press: Boca Raton, FL, US; 2017

***Forensic Examination of Fibres*, 3rd ed**
J. Robertson, C. Roux, K. G. Wiggins
CRC Press: Boca Raton, FL, US; 2017

Forensic Microbiology
D. O. Carter, J. K. Tomberlin, M. E. Benbow, J. L. Metcalf, Eds
Wiley-Blackwell: Somerset, NJ, US; 2017

Forensic Science Handbook, Volume I
R. Saferstein, A. B. Hall, Eds
CRC Press: Boca Raton, FL, US; 2018

Forensic Toxicology
M. Houck, Ed
Academic Press/Elsevier: Waltham, MA, US; 2018

HR Management in the Forensic Science Laboratory, A 21st Century Approach to Effective Crime Lab Leadership
J. M. Collins
Academic Press/Elsevier: Waltham, MA, US; 2018

***Huber and Headrick's Handwriting Identification: Facts and Fundamentals*, 2nd ed**
H. H. Harralson, L. S. Miller
CRC Press: Boca Raton, FL, US; 2017

Network Forensics
R. Messier
Wiley-Blackwell: Somerset, NJ, US; 2017

Pioneers in Forensic Science: Innovations and Issues in Practice
K. M. Pyrek
CRC Press: Boca Raton, FL, US; 2017

***Scientific Examination of Documents: Methods and Techniques*, 4th ed**
D. Ellen, S. Day, C. Davies
CRC Press: Boca Raton, FL, US; 2018

***Stable Isotope Forensics: Methods and Forensic Applications of Stable Isotope Analysis*, 2nd ed**
W. Meier-Augenstein
Wiley-Blackwell: Somerset, NJ, US; 2017

The Sherlock Effect: How Forensic Doctors and Investigators Disastrously Reason Like the Great Detective
T. W. Young
CRC Press: Boca Raton, FL, US; 2018

Understanding Victimology: An Active-Learning Approach
S. Clevenger, J. N. Navarro, C. D. Marcum, G. E. Higgins
CRC Press (Routledge): Boca Raton, FL, US; 2018

Veterinary Forensics: Investigation, Evidence Collection, and Expert Testimony
E. Rogers, A. W. Stern
CRC Press: Boca Raton, FL, US; 2018

Book Review

Poisons: An Introduction for Forensic Investigators

David J. George
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Reviewed by

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Poisons: An Introduction for Forensic Investigators provides a foundational overview of poisons that may be encountered in a forensic setting. This book is intended to provide forensic investigators with a wide range of possible poisons and situations that could be encountered during a crime scene or subsequent investigation.

The book is an introduction to the topic of poisons and is written at a level that is easy to understand, even for individuals without a scientific background. The author, Dr. David J. George, simplifies complex concepts and presents the information for a diverse readership: law enforcement, crime scene investigators, forensic scientists, legal professionals, students, and other interested parties. Dr. George is a clinical toxicologist and general pharmacologist with over 40 years of experience.

This 385-page book comprises 3 sections, 38 chapters, and over 230 case studies. Case studies are provided at the end of each chapter to not only keep the reader engaged but also ensure an awareness of the signs, symptoms, and consequences of poison exposure. Appendices include a glossary and an index of the case studies, so the reader can easily find cases related to a specific type of poison.

Section I begins with an introduction to poisons where the author broadly defines a poison, or toxicant, as "any chemical that produces toxic results". This section discusses potency, dosage, and mechanisms of toxicity. Additionally, exposure, absorption, biodisposition, detection, and treatment are discussed in detail. Although this is a technical topic, the author simplified the material effectively. Additionally, many of the case studies in this section provide interesting examples of poisonings through unexpected means. For example, one case in this section discusses the death of a 17-year-old female who died due to the overuse of sports creams for muscle aches. The regular use of these creams led to a buildup of toxic quantities of methyl salicylate. This case, along with many others throughout the book, demonstrates that the dose of a substance plays a large role in the level of toxicity and ultimate outcome. In other words, "the dose makes the poison", as stated by Paracelsus, often called the Father of Modern Toxicology.

Section II, titled "Potential Poisons", discusses a range of substances that a forensic investigator may encounter during a case. This section details many poisonous natural and synthetic chemicals, such as medications, industrial chemicals, pesticides, and different classes of drugs and recreational substances. Each chapter within this section details a different type of substance; for example, a chapter is dedicated to each of the following: ethylene glycol (typically found in antifreeze), food poisoning, pesticides, strychnine (commonly found in pesticides), plants, and more.

Furthermore, a portion of Section II is dedicated to substances that are typically used recreationally, such as alcohol, stimulants, emerging recreational psychotropics, and opioids. With the ongoing opioid and other abused drugs crises in the United States, these chapters provide information and case studies that are both useful and relevant.

Section III focuses on the circumstances under which a poisoning may occur. This section discusses accidental, suicidal, and homicidal poisonings. Some topics include health care serial poisoners, drug-facilitated crimes such as sexual assault, assassination, and celebrity drug deaths. The content and case studies covered in this section remind investigators to consider all possible scenarios for a given situation. For example, one case study illustrated the possibility of accidental asphyxiation from the carbon dioxide released by dry ice. In this case, the individual did not die, but Dr. George comments that, had the situation ended differently, an inexperienced investigator may not have properly evaluated the situation. Exposure to case studies like these help forensic professionals to be more aware of the unusual situations they may encounter.

Overall, this book is a comprehensive resource for law enforcement, crime scene investigators, forensic scientists, and others who are interested in learning more about poisons and their effects on the human body. Dr. George offers a clear and concise view of this subject matter taken from his years of experience in the field. The writing style of the author engages readers of various backgrounds, and the book provides an exceptional introduction to an extensive topic. The combination of technical content and case studies makes this book an informative, yet interesting, read that fosters the awareness of situations and outcomes that can arise from exposure to a toxicant.

COMMENTARY

"Expert Opinion" Testimony Under Fire

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With over 40 years in the profession, this author has served as a practitioner, public crime laboratory director, and president of several major forensic science professional organizations. And yet, he is puzzled by current discussions of the utility and use of certain classes of forensic science expertise and whether they ought to be admissible evidence in court. These issues are legal ones and the courts will ultimately have to resolve this challenge.

When an expert witness testifies, "In my expert opinion, the latent prints collected at the crime scene and those of the suspect match", what does this really signify? Can the expert state unequivocally that the fingerprints recovered from the crime scene were those of the suspect? What is the level of certainty implied by the expert? Can an expert be absolutely sure that the crime scene prints came from one person, to the exclusion of all others? We want to believe that fingerprints are unique to one person and to no one else. Is this conviction an irrefutable fact? Before now, such questions might have been considered heretical.

The truth is that experts cannot make absolute statements about source attribution. The data are not available. Certainly, crime scene prints can never be compared to all fingerprints in the world, region, or area. Lacking statistical data, experts can only rely on their training and experience. Opinions are subjective. Perhaps a more nuanced explanation is needed to explain the basis of an opinion and more information ought to be provided the court and jury to aid in understanding the basis on which the opinion is founded. Perhaps an additional question can be asked: How certain should an expert be to provide opinion testimony to the trier of fact to aid in understanding the conclusion and is there a standard among experts for stating an opinion?

Certainly, the problem is language and a lack of precise meanings to express sameness. Words are insufficient to express the meaning of the relationship between two items of pattern evidence. What do statements made by expert witnesses such as "the same", "identical", "match", or "consistent with" actually mean to a layperson? When an expert testifies that, for example, two fingerprints "match", what does that opinion mean? There is insufficient data to express the degree of certitude other than a subjective opinion for a layperson to understand how meaningful an association is. Only sufficient data could resolve this issue and allow an expert to associate evidence by means of statistics to value an opinion.

Forensic scientists are partly to blame for the assault on our profession by claiming absolute certainty in associations. By extension, defense attorneys and academics have come to describe forensic science as "junk science". Likely a better description would be, "junk testimony[a]". Expert witnesses in criminal cases had long become accustomed to making unqualified statements concerning the relationship between items of evidence by using subjective observations, not objective measures, to make their cases. Opponents have every reason to question the trustworthiness of subjective opinions and demand that experts prove their claims of confidence and reliability.

For sake of argument, let us agree that critics have a point, that some aspects of forensic science are not as robust as we might wish. This begs the question: what ought to be done? Some contend that certain types of forensic science conclusions routinely proffered in court should be inadmissible. Others argue that such a practice "throws the baby out with the bathwater". Providing juries with expert evidence can assist in understanding the meaning of comparative evidence, provided conclusions are not overstated.

The issue goes beyond what factual or truthful expert testimony is, but rather how judges interpret expert testimony. If expert evidence proffered by forensic scientists requires statistical data to support it to be admissible, should this not apply to any expert testimony?

If we consider court precedents and rules governing expert testimony, we may reach a conclusion. The law makes a distinction between lay witnesses and expert witnesses, and gives the latter greater leeway in offering opinions to the court. There is a wide range of expertise that experts may possess which allows them to offer opinion testimony. The trial judge decides who is an expert. An expert may be a scientist or any person with knowledge gained through education, training, or experience. Experts

[a] The term was coined by Douglas M. Lucas (former head of the Forensic Science Centre, Ontario, Canada) at *The 2017 International Association of Forensic Science Conference* in Toronto (*Forensic Sci Int* 277:139; 2017).

may offer opinions on matters within their knowledge even if statistical data are unavailable. Subjective knowledge appears to be appropriate in many cases.

Indeed, courts routinely consider evidence by social scientists, psychologists, psychiatrists, and medical doctors who may lack the degree of data that some would like to see. In these cases, the defense has every reason to question what allowed the expert to make his or her conclusions and the degree of certainty he or she has. The expert has the obligation to explain, in whatever detail is required to establish his or her opinion.

Over the years there have been sobering reminders that subjective observations do not always work out well. Eyewitness testimony, long thought to be near faultless, has been shown to be less than perfect and has led to miscarriages of justice. The witness pointing to the defendant in the court room and exclaiming, "That's him!" no longer has the same standing as it once did. Analyses of trace elements found in bullet lead to determine a common source of a bullet recovered from a crime scene and a box of ammunition recovered from a suspect's possession has been shown to be unreliable. The reliability of bitemark identification has been open to challenge in recent years, as has hair examination used to assert that hair comes from a particular person.

Science, medicine, technology — all knowledge — is not static but is continuously changing, and our understanding changes along with it. As "gatekeepers", judges cannot be experts in all fields and must rely on experts to help inform their opinions. Prosecutors and defenders must be able to ask tough questions of opposing experts proffering technical evidence and to challenge testimony as is necessary. Expert witnesses need to explain their findings in complete and understandable fashions to judges and juries.

In conclusion, government experts must stop making absolute statements about their opinions. Reports or testimony stating that the test results or opinions are absolute or positively connect a defendant to a crime should be considered "red flags" to judges and lawyers and raise significant doubts. Finally, some form of forensic science oversight should be established by the federal government or state governments. There are few professions that provide services to the public that have no oversight. Some states have taken this course that may help to bring public confidence back to forensic science.