Basic Research to Support the Forensic Sciences: 2012 Awards by the National Institute of Justice

In 2012, NIJ awarded nearly $5 million in basic research grants to help increase the strength of the forensic science disciplines. The mission of NIJ's basic research portfolio is to: 1) develop subsequent applied research and advancements in technologies, and 2) improve the capabilities of crime laboratories to more effectively identify, collect, preserve and analyze forensic evidence.

Here are brief descriptions of the 11 basic research awards made in 2012.

Forensic Biology

The criminal justice problem: In certain criminal cases — particularly, sexual assaults — the evidentiary value of DNA is greatly enhanced if the type of stain (blood, semen, saliva) can be identified. For example, the presence of sperm or saliva may indicate that a sexual assault was committed, but skin cells might be consistent with innocent contact. Similarly, blood under a fingernail would be consistent with a violent act, but skin cells might simply indicate a handshake. The procedures currently used to detect body fluids have limitations, and methods do not yet exist for certain body fluids (for example, vaginal fluid, menstrual blood).

NIJ made two awards to address this problem:

Recipient: Florida International University

The research: Through this grant, researchers headed by Dr. Bruce McCord will investigate the potential for DNA methylation patterns to detect body fluids and dried stains. The goal is to develop epigenetic methylation markers for detection of different tissue types present in forensic evidence. Epigenetics is a rapidly expanding field, especially in cancer diagnostics, in which aberrant methylation sites in the DNA can be used to probe cell differentiation. Generally speaking, methylation of DNA at promoter regions blocks transcription and silences gene expression, permitting cell differentiation. As a result of this process, certain locations in the genome known as CpG islands are methylated in a tissue specific fashion. These loci can be exploited using bisulfite modification, which converts unmethylated cytosines to lower melting uracils, followed by polymerase chain reaction (PCR) amplification and analysis using pyrosequencing or real-time PCR melt curves. It is hypothesized that this information can be used to identify body fluid stains.

The researchers in Dr. McCord's laboratory will also work with Dr. Kuppareddi Balamurugan at the University of Southern Mississippi, the Broward Sheriff's Office DNA laboratory, and Qiagen Inc. to develop forensic loci that are differentially methylated in blood, skin, saliva, sperm and vaginal epithelia cells. Preliminary findings using a panel of markers that include C20orf117, ZC3H12D, BCAS4 and FGF7 have already demonstrated the capability to accurately and specifically detect these fluids in clinical samples. To find additional loci, the researchers will use next-generation sequencing to scan four or five individuals to detect methylation-specific differences in their chromosomes. Once loci have been identified, they will develop methylation-specific PCR primers capable of identifying semen, saliva, blood, vaginal epithelial cells and skin cells. Then, using bisulfite modification and multiplex PCR amplification followed by pyrosequencing and real-time PCR, they will determine cell-specific methylation patterns that, if successful, could someday allow forensic examiners to identify the source of single and mixed biofluids recovered from crime scenes.

Recipient: Virginia Commonwealth University

The research: Through this grant, researchers under the leadership of Dr. Zendra Zehner will attempt to identify novel, body-fluid specific miRs in forensically important biological fluids. The goal is to settle inconsistencies in previous studies and begin to characterize miRs according to forensic developmental validation guidelines. To do this, the researchers will use deep sequencing (a "next-generation sequencing" method) to analyze the eight common forensically relevant body fluids (blood, seminal fluid from normal and vasectomized males, sweat, vaginal fluid, urine, feces, saliva and menstrual blood). Population samples of each body fluid will be analyzed for characterization across gender (if appropriate), ethnicity and age. This will also enable comparisons of relative abundance and detection thresholds of the miRs in question. Samples from the same individuals over a short period of time will assess detectability of miRs throughout the menstrual cycle (for vaginal secretions and menstrual blood) or dietary and hydration changes (for saliva, urine and feces).

Toxicology

Recipient: Research Triangle Institute (RTI)

The criminal justice problem: Designer drugs, such as synthetic cannabinoids and cathinones, have become increasingly prevalent. Detection of these drugs is a challenge because as bans on specific compounds go into effect, manufacturers rapidly substitute closely related analogs for the newly banned substances, creating a constantly moving analytical target. Most forensic laboratories do not have the research capability to keep up with the rapid turnover of designer drugs that are being marketed for recreational use. Because of the rapid emergence of these new drugs, little is currently known about their pharmacological and toxicological profiles. Also, the consequences of long-term usage have not yet been studied, and behavioral and metabolic studies have been performed on only a relatively limited number of compounds.

The research: The RTI researchers will 1) determine the stability of currently popular designer drugs and identify major degradation products, including pyrolysis products, and 2) identify their major metabolites. For designer drugs that are typically processed into herbal formulations and smoked, such as synthetic cannabinoids, the researchers will identify the primary components of smoke produced by burning the analytes in formulations typically reported by recreational users. Although the researchers will begin with synthetic cannabinoids and cathinones, it is anticipated that the research will expand to other classes of compounds as they become popular. To this end, RTI is partnering with the Virginia Department of Forensic Science, which will keep the researchers apprised regarding compounds that are being encountered in real-world cases and help ensure that priorities are consistent with the needs of the forensic community. This project should result in a reliable data set for forensic laboratories across the U.S. to use in developing assays for detection of use and for confirming the presence of the parent compound within residues.

Bloodstain Pattern Analysis

Recipient: North Carolina State University

The criminal justice problem: Additional work is needed to establish the underpinning science of bloodstain pattern analysis (BPA), such as fluid dynamics. In particular, there has been minimal comprehensive research on the complex phenomena of bloodstain patterns on textile materials.

When blood is deposited on fabrics, it tends to migrate ("wick") along the fibers of the fabric. This makes BPA difficult due to the strong interaction between the blood deposition process, the fabric structure and the surface properties. Another complication is the wide range of textile materials and their surface treatments, including fabric and yarn construction and fiber types. A fundamental analysis of the deposition of blood onto fabric structures — and the subsequent movement of blood into or across the fabric — is needed to develop models that could define the scope and limitations of BPA on textiles.

The research: Researchers will study the mechanics of the formation of bloodstain patterns on the most common fabric surfaces used in the clothing and home furnishing industries. For each type of formation — drip, spatter and transfer — research will be conducted on woven fabrics (such as the plain woven cotton used in bed sheets), cotton twill (such as denim), and knit fabrics (such as those used in cotton jersey knit T-shirts). The research will also produce quantitative models to allow predictions regarding the wicking behavior of blood into these fabrics.

Forensic Entomology / Medicolegal Death Investigations

Recipient: Sam Houston State University

The criminal justice problem: Although much research has been completed on decomposition of a corpse as related to post-mortem interval estimation, the bacterial basis of decomposition or its function in insect recruitment or repulsion is currently being explored. The National Research Council's Committee on Identifying the Needs of the Forensic Science Community (2009) called for a better understanding of decomposition as a mosaic ecosystem, rather than as a static snapshot in time, which fails to consider the dynamic process of decomposition.

The research: This award will support a holistic investigation to unite the fields of microbiology, entomology and chemistry to better understand the ecosystem of decomposition. To characterize the bacterial species community (microbiome) through the entire decomposition process, the researchers plan to:

- Identify bacteria — introduced by the soil and flies — that are significant to the body's decomposition process.
- Collect and characterize gasses emanating from the cadaver at various times during decomposition.
- Correlate species of insects present with bacteria present by linking them through their bacterial gaseous byproducts.
- Design comparative and forecasting models to characterize the change in bacterial and insect succession through time, which will ultimately aid in estimation of the post-mortem interval.

Forensic Entomology

Recipient: Texas AgriLife Research

The criminal justice problem: Predictable patterns in the development of the blow fly are used by forensic entomologists to estimate a post-mortem interval (PMI). However, these can be imprecise for later stages of blow fly development, thus leading to large margins of error in PMI estimation.

The research: Through this award, researchers will identify the genetic markers of developmental progress — and genotypes with fast or slow development rates — in *Cochliomyia macellaria,* a blow fly species commonly encountered in death investigations, including the study area of south-central Texas. The results of this research may allow forensic entomologists to better predict a range of

developmental progress in blow flies. Such a genomics-based approach in a death investigation may reduce error in a PMI estimate by pinpointing more specific periods of immature blow fly development and by accounting for genetic and environmental effects on blow fly development.

Forensic Pathology

Recipient: University of New Mexico Health Sciences Center

The criminal justice problem: In determining cause and manner of death during a standard post-mortem examination, injuries and trauma may be either overlooked, or artifacts added, during the standard gross autopsy. Imaging technologies are being explored to overcome these issues.

The research: Magnetic resonance (MR) imaging provides excellent sensitivity to subtle changes in soft tissue. Through this award, researchers will use animal tissue to examine the impact of post-mortem interval and tissue temperature on MR imaging parameters. This work is expected to lead to the development of systematic procedures for post-mortem MR to evaluate cause, manner and time of death and specific injuries or pathologies noninvasively. In addition to its criminal justice value, this basic research could prove valuable for a number of fields, including biology, veterinary medicine and human medical research.

Trace Evidence: Fiber Analysis

Recipient: St. Olaf College

The criminal justice problem: The majority of trace evidence, such as fibers, hair with no follicular tag for DNA analysis, glass, and polymers, cannot conclusively be linked to a specific exemplar with a high degree of certainty. Fibers found at a crime scene can be analyzed chemically or morphologically and be found to be consistent with fibers found in a suspect's possession, but the same can likely be said about fibers found in the possession of hundreds of innocent people. This limits the discriminatory power of trace forensic evidence from a crime scene to a single suspect.

Isotope ratio analysis, using isotope ratio mass spectrometry (IRMS), holds promise for improving the discriminatory power of trace-evidence analysis. Forensic IRMS may allow trace evidence to be linked to a single suspect or source with a high degree of certainty, increasing the probative value of trace evidence. Development of an IRMS technique for fibers will also expand the number of forensic applications where IRMS can be of significant value.

The research: Through this grant, researchers will develop forensically useful methods for the differentiation of fibers based on isotope ratio mass spectrometry for criminal justice purposes that potentially help link to a single suspect or source with a high degree of certainty. Researchers will use IRMS to determine the isotope ratios, namely $\delta 2H$, $\delta 13C$, $\delta 15N$, and $\delta 18O$, for fibers that are otherwise chemically and physically identical. Researchers will also create isotopic composition plots using combinations of isotopes as well as plots that compare three isotopic compositions to determine the isotopic compositions with the most discriminatory power for the samples. Statistical analysis will be used to determine similarities or differences between fibers.

Trace Evidence: Laser-Induced Breakdown Spectroscopy

Recipient: University of Central Florida

The criminal justice problem: Over the past decade, laser-induced breakdown spectroscopy (LIBS) has proved its scientific value in performing elemental analysis of forensic trace evidence, such as cotton, glass, paint, paper and ink, and soil. Despite its recognition by the scientific community, LIBS is not commonly accepted in a court of law. This is primarily because there are no operation standards or known error rates for LIBS. Currently, the identification of elemental information from the LIBS spectrum relies on the assignment of spectral lines based on wavelength tables. However, these tables have been established by arc excitation that does not reproduce the excitation conditions of LIBS that add dynamic shift and broadening to the spectral line. In addition, the low spectral resolution of LIBS systems makes it possible for spectral interferences to occur for the majority of the lines, which yields an uncertain elemental profile.

The research: Through this grant, researchers under the leadership of Dr. Matthieu Baudelet will quantify the level of confidence in an elemental analysis by LIBS through creation of the parameter representing the level of confidence, experimental measurement of the level of confidence, and confirmation of the procedure by blind testing.

Trace Evidence

Recipient: University of Central Florida

The criminal justice problem: More effective covert taggants (nanoparticles encapsulated in microspheres) might help to identify criminals and terrorists, track and trace objects, authenticate documents, and detect tampering activities. Although nanoparticles have shown great potential as covert taggants, their use in tagging every object in a large group of objects is limited by a lack of nanoparticle-specific property and low level of multiplicity (small coding space).

The research: Through this grant, researchers headed by Dr. Ming Su will develop a new nanoparticle-based covert taggant system, where a panel of phase change nanoparticles (such as metals and eutectic alloys) that have sharp and discrete melting peaks will be encapsulated in silica or polymer microspheres and used as covert taggants (smart dusts).

The goals of this project are to:

- Demonstrate that colloid synthesis can be used to construct millions of unique, information-rich and covert thermal taggants.
- Confirm that thermal taggants can be easily incorporated into real-world items.
- Test whether thermal taggants can be recovered, detected and decoded from tagged items.

The concept of thermal taggants is new and potentially transformative and can be applied to many forensic science areas.

Controlled Substances

Recipient: Auburn University

The criminal justice problem: Synthetic cannabinoids — which have no recognized therapeutic use — continue to be manufactured, distributed, imported and abused. This poses a threat to public safety. Although many of these illegal drugs have recently been categorized as “Federal Schedule 1 control,” a number of their precursor materials (especially the “JWH compounds”) are commercially

available and, therefore, cannot be legally controlled. As the past several decades have revealed — witness the production and use of amphetamines, MDMA, piperazines and bath salts — there is likely to be further development and production of new designer drug derivatives. Many of the aromatic ring substituted precursor materials (known to enhance CNS hallucinogenic or entactogenic activity in the phenethylamines, bath salt and piperazine drugs of abuse) are commercially available and can be readily incorporated into the structural framework of the JWH-style indole cannabinoid compounds. The "substituted indoles" area of drug and organic chemistry needs further study, as it represents a relatively new category of drugs of abuse.

The research: Researchers will perform an extensive forensic chemical study of isomeric indoles of the JWH style. First, they will address the uniqueness of the 1,3-indole ring substitution pattern to determine whether the spectral data obtained from the 1-alkyl-3-acylindoles are unique to only the 1,3-indole ring substitution pattern. It is already known that the precursor chemicals are available to prepare the acyl group substituted indole for every indole ring position — but although the 1-alkyl-3-acylindoles are the most likely candidates for the clandestine market, it is important for forensic chemists to know whether analytical data eliminates the other isomeric indole ring substitution patterns of the equivalent substituent.

To help forensic drug chemists specifically identify compounds to determine if they are an analog of a controlled substance, this research project will investigate the forensic analytical chemistry of these potential future designer substances. Finally, the research will look at the relationship between drug/isomer structure and analytical properties such as mass spectral fragmentation through the synthesis and analysis of labeled (isotopic and homologous labels) synthetic cannabinoid compounds.