# *Research Needs in Trace Evidence Analysis: How Can Better Data Help?*

*Trace Evidence Data Workshop*

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*Gerry LaPorte*
*Director*
*Office of Investigative and Forensic Sciences*
*National Institute of Justice*

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# Disclaimer

- Opinions or points of view expressed are those of the presenter and do not necessarily reflect the official position or policies of the U.S. Department of Justice

# Mission of NIJ's Office of Investigative and Forensic Sciences

- To improve the quality and practice of forensic science through innovative solutions that support research and development, testing and evaluation, technology, and information exchange for the criminal justice community

# Research Objectives: Trace Evidence

- Strengthen the accuracy, reliability and validity of trace evidence methods
- Develop new tools and techniques to detect, collect and preserve evidence from crime scenes
- Invest in innovative strategies that decrease the time and labor needed for trace evidence analysis
- Support new approaches and enhancement of current approaches to interpret trace evidence data

# NIJ Technology Working Group (TWG) Needs Assessment

| Technology Working Group Operational Requirements Updated Fall 2015 | Scientific Research | Technology Development | Policy or Protocol Development | Assessment & Evaluation | Dissemination &/or Training | Other | Forensic Discipline |
|---|---|---|---|---|---|---|---|
| Scientific foundations for the evaluation of evidence in support of qualified and definitive conclusions. | X | X | | | | | Impression & Pattern/ Trace Evidence |
| Forensically relevant approaches to the statistical interpretation of evidence. | X | X | | X | X | X | Impression & Pattern/ Trace Evidence |
| Determination of accuracy for forensic conclusions, including potential sources of error. | X | X | | | | X | Impression & Pattern/ Trace Evidence |
| Support for standards development and validation of forensic methods. | X | | X | | | X | Impression & Pattern/ Trace Evidence |
| Evaluation of varied types of technical review and verification of casework. | X | | X | X | | X | Impression & Pattern/ Trace Evidence |
| Novel and/or improved evidence recognition, collection, and visualization tools and analytical instrumentation. | X | X | | X | X | | Impression & Pattern/ Trace Evidence |
| Evaluation of sequential evidence processing methods. | X | X | | X | | | Impression & Pattern/ Trace Evidence |
| Fundamental understanding of how environmental factors can affect evidence. | X | | | | | | Impression & Pattern/ Trace Evidence |
| Evaluation of the effects of training, accreditation and certification on the accuracy of conclusions. | | | X | X | | | Impression & Pattern/ Trace Evidence |
| Understanding of the cognitive processes involved in pattern recognition as applied to forensic identification. | X | | | | | | Impression & Pattern/ Trace Evidence |
| Quantitative methods of analysis to augment visual trace evidence examinations. | X | X | | X | | X | Trace Evidence |

http://nij.gov/topics/forensics/documents/2015-forensic-twg-table.pdf

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# NIJ Support for Trace Evidence R&D

| Year | Total R&D Awards | Total Trace Evidence Awards | Percentage of Trace Evidence Awards |
|---|---|---|---|
| FY 2009 | 45 | 6 | 13.33% |
| FY 2010 | 67 | 8 | 11.94% |
| FY 2011 | 33 | 6 | 18.18% |
| FY 2012 | 35 | 9 | 25.71% |
| FY 2013 | 41 | 7 | 17.07% |
| FY 2014 | 48 | 3 | 6.25% |
| FY 2015 | 60 | 11 | 18.33% |
| **Total:** | **329** | **50** | **15.20%** |



Trace Evidence Awards vs. Total R&D Awards

Legend: Total Awards for All Disciplines — Number of Trace Awards
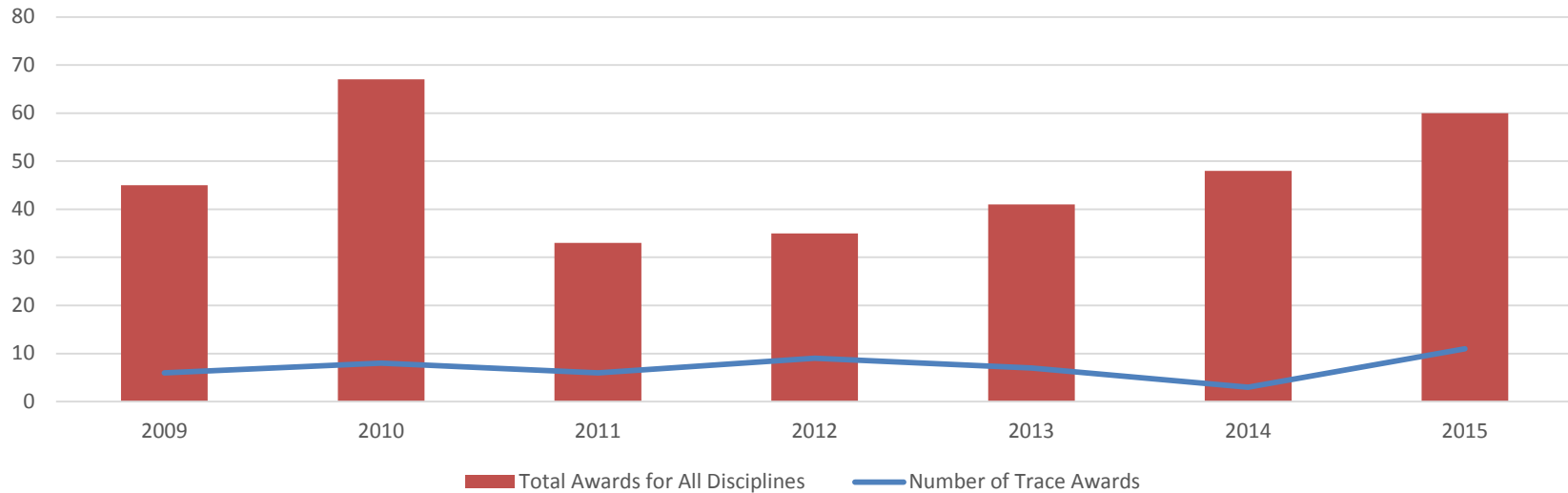
# NIJ Support for Trace Evidence R&D

| Year | Total R&D Funding | Total Trace Evidence Funding | Percentage of Funding for Trace Evidence |
|---|---|---|---|
| FY 2009 | $25,185,924 | $2,208,647 | 8.77% |
| FY 2010 | $32,982,037 | $2,471,878 | 7.49% |
| FY 2011 | $16,289,756 | $2,006,447 | 12.32% |
| FY 2012 | $15,014,155 | $3,150,821 | 20.99% |
| FY 2013 | $15,188,068 | $1,859,972 | 12.25% |
| FY 2014 | $22,991,001 | $1,471,103 | 6.40% |
| FY 2015 | $28,730,920 | $5,759,064 | 20.04% |
| **Total:** | **$156,381,861** | **$18,927,932** | **12.10%** |



Trace Evidence Funding vs. Total R&D Funding
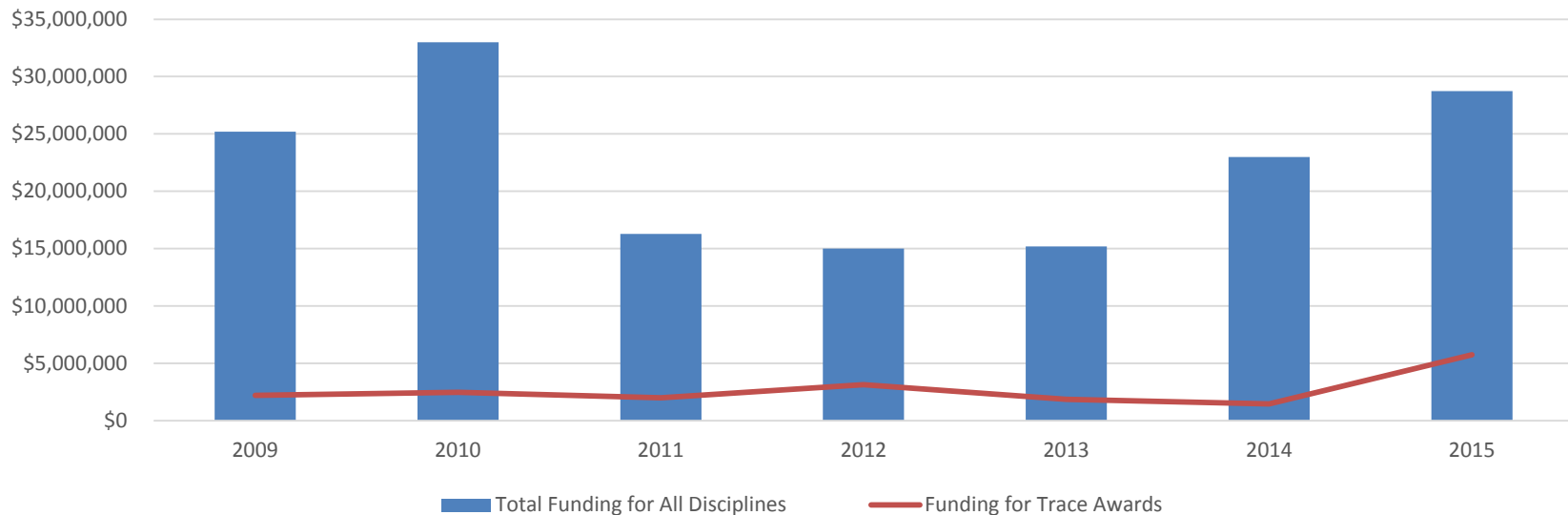
# NIJ Trace Evidence R&D Funding

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| **Total:** | **$18,927,932** |

Funding for Trace Awards
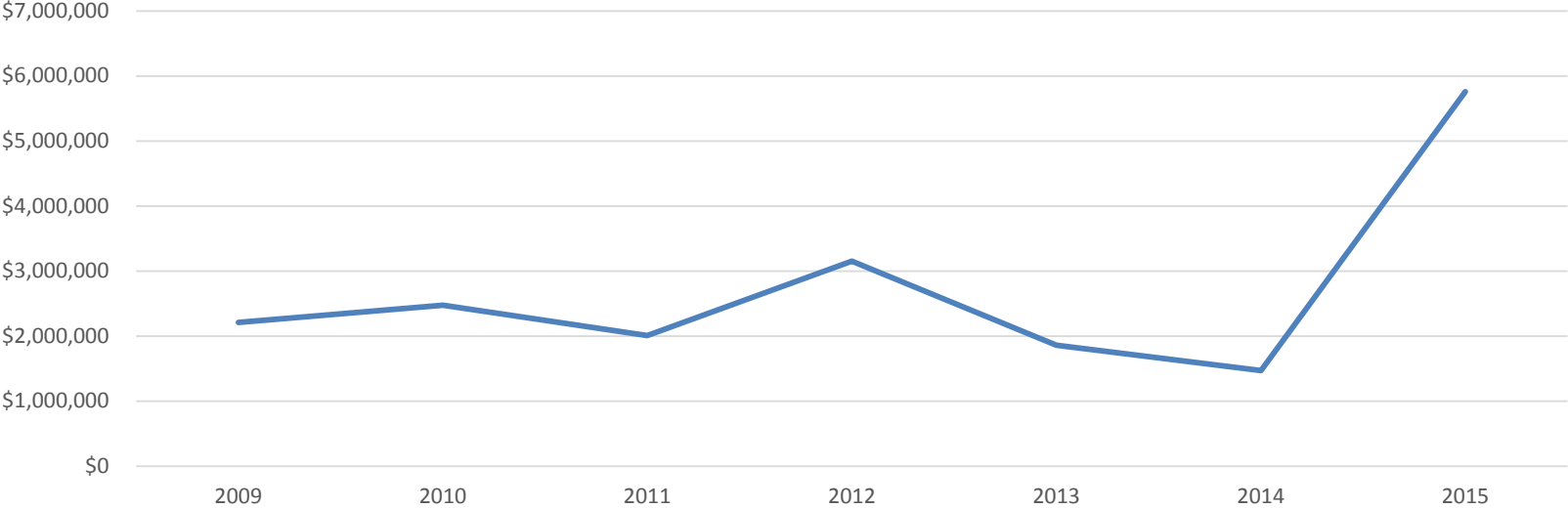
# NIJ Trace Database/Compendia Efforts

## Paints, Pigments and Dyes

- *Fundamentals of Forensic Pigment Identification by Raman micro-spectroscopy: A practical identification guide and spectral library for forensic science laboratories;* Microtrace, LLC (Christopher Palenik)

- *Raman Spectroscopy of Automotive and Architectural Paints: In situ Pigment Identification and Evidentiary Significance;* Microtrace, LLC (Christopher S. Palenik)

- *Development of an Analytical System for the Forensic Comparison and Identification of Fiber Dyes on Casework-Sized Fibers;* Microtrace, LLC (Christopher S. Palenik)

## Fire & Arson Investigation

- *NCFS Support of SWGDE and T/SWGFEX Projects/Activities – T/SWGFEX Portion;* University of Central Florida (Michael Sigman)

- *Substrate Pyrolysis Database Expansion, Evaluation and Use;* University of Central Florida (Michael Sigman)

## Smokeless Powder & Explosives

- *Smokeless Powder Reference Collection and SWGFEX Smokeless Powders Database Expansion;* University of Central Florida (Michael Sigman)

## Particles

- *Nanotrace: Applications of subvisible to nanoscale particles in trace evidence;* Microtrace LLC Christopher Palenik

## Microbiome

- *Construction of the Forensic Microbiome Database with Enhanced GeoSourcing;* J. Craig Venter Institute

# Trace Database/Compendia Examples

*Fundamentals of Forensic Pigment Identification by Raman micro-spectroscopy: A practical identification guide and spectral library for forensic science laboratories*

Microtrace, LLC

PI: Dr. Christopher S. Palenik

- Provide forensic science laboratories with the fundamental research, spectral database, classification scheme and basic guidelines for the examination of paint pigments in forensic evidence. This work included:
  - Development of a thorough spectral pigment database.
  - Supporting analyses to check that the analyzed pigments were consistent with their labels.
  - Development of an objective Quality Index for ranking the provenance of a pigment sample.
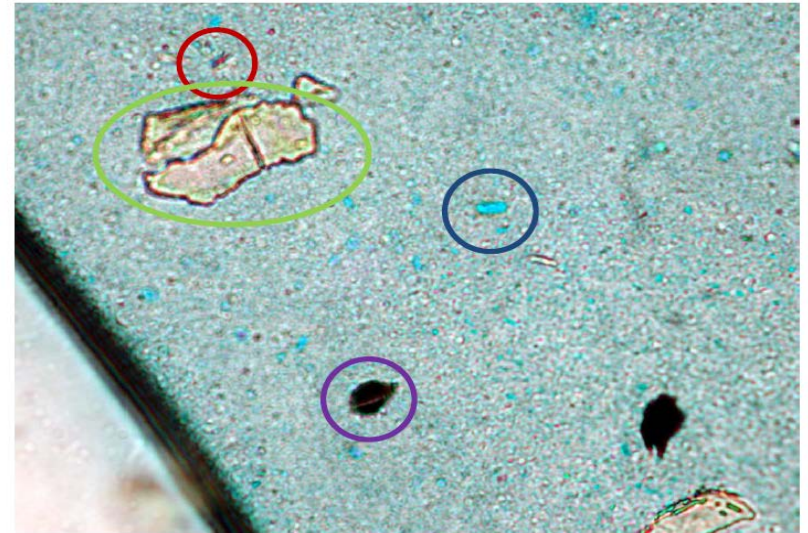


**Figure 1:** Thin section of a blue paint showing the presence of four different pigments observed in plane polarized transmitted light (mounted in xylene). Blue pigments (blue circle), with a varying size range, which dominate the paint. Red pigments (red circle), which are less commonly observed, and then two larger effect pigments such as mica (green circles) and an opaque metallic flake (purple circle).

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# Trace Database/Compendia Examples

*Smokeless Powder Reference Collection and SWGFEX Smokeless Powders Database Expansion*

University of Central Florida

PI:  Dr. Michael Sigman

- Expand the National Center for Forensic Science (NCFS) Smokeless Powders Database (http://www.ilrc.ucf.edu/powders/) to contain over 800 records covering both legacy and newly purchased smokeless powders.

- Address the need for reference materials by providing a set of 100 smokeless powder samples to each of 50 ASCLD/LAB accredited laboratories. Data from the NCFS analysis of each reference material was entered into the Smokeless Powders Database.

- Utilized the Smokeless Powders Database to provide a statistical assessment of the value of a match between a database record and the physical and chemical properties of a questioned sample.

# Trace Database/Compendia Examples

*Substrate Pyrolysis Database Expansion, Evaluation and Use*

University of Central Florida
PI:  Dr. Michael Sigman

- Further development of the Substrate Database ([http://ilrc.ucf.edu/substrate/](http://ilrc.ucf.edu/substrate/)) to aid in the evaluation of fire debris casework samples.
    - Facilitate development of a new cross tabulation between pyrolysis/combustion products and ignitable liquid components.
    - Increase the range of substrates and the diversity of observed  pyrolysis/combustion products
    - Collaboration with the Ignitable Liquids Database Committee, originally formed under the Scientific Working Group for Fire and Explosions (SWGFEX).
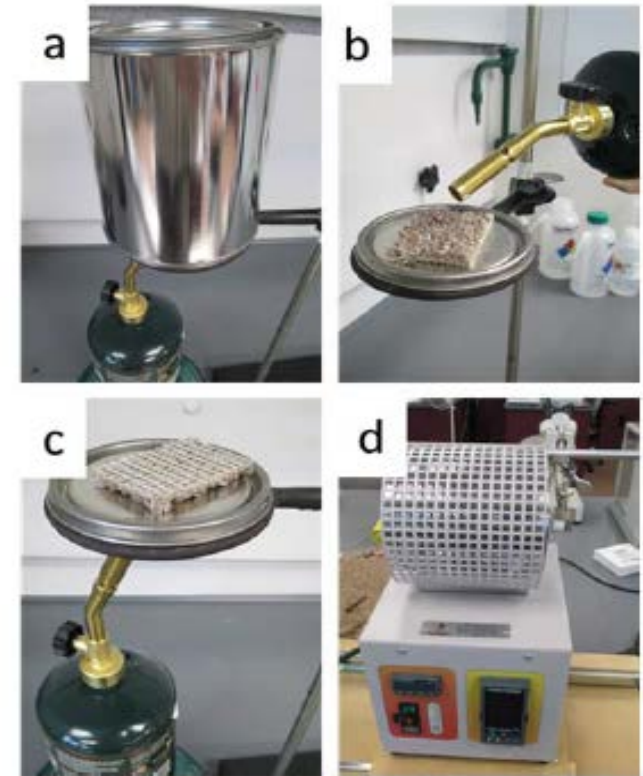


Figure 4. (a) Pyrolysis/combustion method 1, (b) method 2, (c) method 3, (d) method 4.

# Impact of Trace Evidence Data

*Casework*

- ***Isotope Analyses Of Hair As A Trace Evidence Tool To Reconstruct Human Movements: Combining Strontium Isotope With Hydrogen/Oxygen Isotope Data**;* IsoForensics, LLC

*Standards*

- ***Elemental Analysis of Glass by SEM-EDS, XRF, EPMA, LIBS, and LA-ICP-MS**; Florida International University

- ***LA-ICP-MS and LIBS Analysis of Paper, Inks, Soils, Cotton, and Glass**; Florida International University

- ***Strengthening the Evaluation and Interpretation of Glass Evidence using Statistical Analysis of Collection sets and Databases of Refractive Index and Elemental Data (uXRF, ICP-MS and LA-ICP-MS)**; Florida International University

# Impact of Trace Evidence Data

*Isotope Analyses Of Hair As A Trace Evidence Tool To Reconstruct Human Movements: Combining Strontium Isotope With Hydrogen/Oxygen Isotope Data*

IsoForensics, LLC

PI:  Dr. Brett Tipple

Research to determine if the $^{87}Sr/^{86}Sr$ ratios of human hair related to a geographically controlled variable.

1. Develop analytical methodologies
2. Establish protocols for the isolation of the endogenous and exogenous Sr signals within human hair.
3. Determine the geospatial relationship between the $^{87}Sr/^{86}Sr$ ratios and a geographically mediated parameter and expand to the city-, region-, and nation-scale.
4. Compare Sr and oxygen (O) isotope ratios along the hair length of known travelers, establish a relationship between both isotope systems, and determine if the 87Sr/86Sr ratios reflect known geographic movements in a similar fashion as O isotope ratios.

## Inside the search to identify Deer Island girl

**Turning to advanced science**

While investigators searched for Baby Doe's dental records, they were also turning to advanced forensic techniques for answers.

Her DNA had already been compared, without a match, with databases of missing children. So they sent a sample to the University of North Texas Health Science Center, for scientists to examine her mitochondrial DNA, which could help identify her immediate relatives.

They sent a single tooth and 200 strands of hair to a lab in Salt Lake City, Utah, called IsoForensics Inc. The oxygen and hydrogen isotopes in her tissue could tell researchers where her drinking water came from, and the strontium isotopes could give them clues about the origins of what she ate and bathed in, said a research scientist at the lab, Brett Tipple. The hair is a historical record of those isotopes, he said, that will show analysts whether and where she moved.

SUZANNE KREITER/GLOBE STAFF

Evidence was sent to Utah for isotope analysis.

# Impact of Trace Evidence Data

*1) Elemental Analysis of Glass by SEM-EDS, XRF, EPMA, LIBS, and LA-ICP-MS*

*2) LA-ICP-MS and LIBS Analysis of Paper, Inks, Soils, Cotton, and Glass*

*3) Strengthening the Evaluation and Interpretation of Glass Evidence using Statistical Analysis of Collection sets and Databases of Refractive Index and Elemental Data (uXRF, ICP-MS and LA-ICP-MS)*

Florida International University
PI: Dr. Jose Almirall

## Status of Standards and Guidelines Recommended for Inclusion on the OSAC Registries

### Standards and Guidelines at FSSB for Vote

*ASTM: E2330-12 Standard Test Method for Determination of Concentrations of Elements in Glass Samples Using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for Forensic Comparisons (for consideration as an OSAC Standard)*

One objective of a forensic glass examination is to compare glass samples to determine if they can be discriminated using their physical, optical or chemical properties (for example, color, refractive index (RI), density, elemental composition). If the samples are distinguishable in any of these observed and measured properties, it may be concluded that they did not originate from the same source of broken glass. If the samples are indistinguishable in all of these observed and measured properties, the possibility that they originated from the same source of glass cannot be eliminated. The use of an elemental analysis method such as inductively coupled plasma mass spectrometry yields high discrimination among sources of glass. This test method covers a procedure for quantitative determination of the concentrations of magnesium (Mg), aluminum (Al), iron (Fe), titanium (Ti), manganese (Mn), rubidium (Rb), strontium (Sr), zirconium (Zr), barium (Ba), lanthanum (La), cerium (Ce), neodymium (Nd), samarium (Sm), and lead (Pb) in glass samples.

*ASTM: E2926-13 Standard Test Method for Forensic Comparison of Glass Using Micro X-ray Fluorescence (µ-XRF) Spectrometry (for consideration as an OSAC Standard)*

This test method is for the determination of major, minor, and trace elements present in glass fragments. The elemental composition of a glass fragment can be measured through the use of µ-XRF analysis for comparisons of glass. This test method covers the application of µ-XRF using mono- and poly- capillary optics, and an energy dispersive X-ray detector (EDS).

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www.nist.gov/forensics/osac/status-of-other-standards-and-guidelines-recommended-for -inclusion-on-the-osac-registries.cfm

# NIJ R&D Microbiome Awards

- From FY 2011-2015, NIJ funded 11 Microbiome-related projects across the following disciplines:
  - Trace Evidence
  - Forensic Anthropology
  - Forensic Pathology
  - Forensic Entomology

- Seven of these projects related to Trace Microbiome:
  - Human trace microbiome
  - Microbial analysis of trace soil evidence

# Current Trace Microbiome Awards

1. ***Evaluating the Skin Microbiome as Trace Evidence*– University of California, San Diego (PI: Rob Knight)**
   - Characterize basic transfer properties of an individual's unique skin microbial community to common surface materials.

2. ***A Predictive Knowledgebase Linking Microbial Signatures to Human Lifestyle Characteristics;* University of Chicago; PI: Dr. Jack Gilbert**
   - Develop a knowledgebase and model linking key features of the human skin microbiome to personal traits about an individual.

3. ***Human Microbiome Species and Genes for Human Identification;* University of North Texas Health Science Center; PI: Dr. Bruce Budowle**
   - Develop a novel MPS targeted metagenomic approach to more accurately characterize complex microbial communities to identify those bacterial species that meet the candidate requirement of being common to all humans and relatively abundant to enhance limit of detection.

4. ***Construction of the Forensic Microbiome Database with Enhanced Geosourcing;* J. Craig Venter Institute; PI: Dr. Rhonda Roby**
   - Establish the Forensic Microbiome Database (FMD)

5. ***Developing Reliable Methods for Microbial Fingerprinting of Soil Evidence: Collection, Contamination, Storage, and Analysis;* Michigan State University; PI: Dr. David Foran**
   - Utilize new tools that have recently become available (and far more affordable) so as to better understand and exploit the complex bacterial makeup of soil for its forensic identification.

# Current Microbiome Trace Evidence Awards

*A Predictive Knowledgebase Linking Microbial Signatures to Human Lifestyle Characteristics*
Argonne National Laboratory
PI: Dr. Jack Gilbert

- The primary goal of the proposed investigation is to develop a knowledgebase and model linking key features of the human skin microbiome to personal traits about an individual.
  1. Define the microbial signature that is characteristic to an individual's place of work
  2. Define the role of uniform human characteristics in shaping the microbial signature of human skin sites and surface samples.
  3. Define the role of non-uniform human characteristics in shaping the microbial signature of human skin sites and surface samples.

# Current Microbiome Trace Evidence Awards

## *Evaluating the Skin Microbiome as Trace Evidence*

University of California, San Diego

PI: Rob Knight

- Overall research goal is to characterize basic transfer properties of an individual's unique skin microbial community to common surface materials.
  1) Determine whether the sequence in which surfaces are touched by the same person influences the detection of an identifiable skin microbial signature.
  2) Determine whether the number of times a surface is touched by the same person influences the detection of an identifiable skin microbial signature.
  3) Determine whether identifiable skin microbial signatures are recoverable after multiple people have touched an object.
  4) Determine the stability of microbial signature on surfaces over time.
  5) Determine the magnitude of change in microbial skin communities during morgue cooler storage (relative to initial samples at death scene).
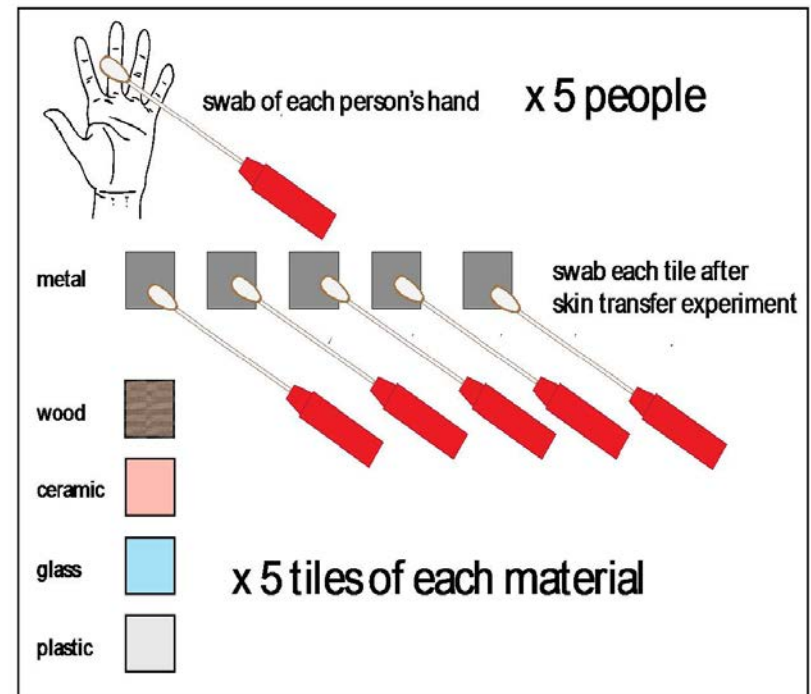


**Figure 2.** A schematic illustrating sampling set-up for Phases 1-4. Each skin transfer experiment will include five participants and five replicates of metal, wood, ceramic, glass, and plastic tiles. Each participant's right hand will be swabbed daily for the five days prior to the beginning of each experiment. Each tile will be swabbed as described below in the experimental design section of each phase.

# Current Microbiome Trace Evidence Awards

*Developing Reliable Methods for Microbial Fingerprinting of Soils*
Michigan State University
PI: Dr. David Foran

- The goal of the research proposed here is to use state of the art molecular and computational techniques to assay the bacterial makeup of soils for forensic identification in a far more comprehensive manner than has ever been accomplished before.

*Developing Reliable Methods for Microbial Fingerprinting of Soil Evidence: Collection, Contamination, Storage, and Analysis*
Michigan State University
PI: Dr. David Foran

- The goal of the research described here is to utilize new tools that have recently become available (and far more affordable) so as to better understand and exploit the complex bacterial makeup of soil for its forensic identification.

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# Current Microbiome Trace Evidence Awards

*Human Microbiome Species and Genes for Human Identification*
University of North Texas Health Science Center
PI: Dr. Bruce Budowle

- This proposal seeks to develop a novel MPS targeted metagenomic approach, using a battery of bacterial housekeeping genes containing conserved and variable regions, to more accurately characterize complex microbial communities to identify those bacterial species that meet the candidate requirement of being common to all humans and relatively abundant to enhance limit of detection.

  1. Develop a housekeeping gene panel for bacterial community profiling.

  2. Validate the bacterial housekeeping gene panel by generating empirical sequence data from mock metagenomic communities.

  3. Use the housekeeping gene panel developed and tested in Aims 1 and 2 to screen 50 unrelated individuals to identify common and the most abundant species among all participants.

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# Current Microbiome Trace Evidence Awards

*Construction of the Forensic Microbiome Database with Enhanced Geosourcing*

J. Craig Venter Institute
PI: Dr. Rhonda Roby

- The purpose of this study is to establish the Forensic Microbiome Database (FMD) that maintains a quality controlled analysis of each sequence in the database, partitions each sequence into an appropriate category or categories, and can be used to assign statistical significance to the data obtained.

    1. Establish the FMD by designing and building the infrastructure for a comprehensive online forensic microbiome database that is free and open to the public and populating the database with 16S sequence and metadata.

    2. Obtain stool and oral swab samples from distinct geographic regions of the world, perform 16S sequencing, and upload these data into the FMD.

# Graduate Research Fellowship Program in Science, Technology, Engineering, and Mathematics (GRF-STEM)

- Supports doctoral research in STEM disciplines in topic areas relevant to criminal justice.
- Beginning in FY2015, NIJ significantly increased fellowship stipend and term length.
- Program visibility and competitiveness are increasing.

| Year | Total Number of GRF-STEM Applications | Total Number of GRF-STEM Awards | Total Number of GRF-STEM Trace Evidence Awards |
|---|---|---|---|
| FY 2012 | 6 | 3 | 0 |
| FY 2013 | 7 | 1 | 0 |
| FY 2014 | 5 (1 trace app submitted) | 3 | 1 |
| FY 2015 | 33 (1 trace app submitted) | 20 | 0 |
| FY 2016 | 40 (7 trace apps submitted) | 22* | 4* |
| **Total** | **91** | **49*** | **5*** |

*Not all FY 2016 recommended awards have been announced.

# Current GRF-STEM Trace Evidence Fellow

**Christy Mancuso** – 2014 Fellow; University of Utah
*Fingernails as Recorders of Region-of-Origin and Travel History*

Christy Mancuso (2014 Fellow) is a Ph.D. candidate in the Department of Biology at the University of Utah, Salt Lake City. Before beginning her doctoral program, Christy earned an M.S. in biomedical forensic sciences from the Boston University School of Medicine. Christy's doctoral research focuses on the use of stable isotope analyses to reconstruct individuals' region of origin and travel history, to aid investigators as they trace the movement of, for example, illegal immigrants and victims of human trafficking.

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# Forensic Technology Center of Excellence (FTCoE)



## Knowledge Transfer



**THE BASICS OF ERROR RATES IN PATTERN EVIDENCE**

Some commonly reported error rates for pattern evidence, and how to calculate them.

**More Details**



**A RETROACTIVE REVIEW OF HAIR MICROSCOPY CASES**

Technology challenges and stumbling blocks associated with the case identification and retrieval process.

**More Details**



**FAMILIAL DNA SEARCH SYSTEM**

Demonstration and evaluation of a secure web enabled search system for multiple DNA profile comparisons.

**More Details**

https://www.forensiccoe.org

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