RDT&E Summary, Challenges, and Way-Ahead

National Commission on Forensic Science

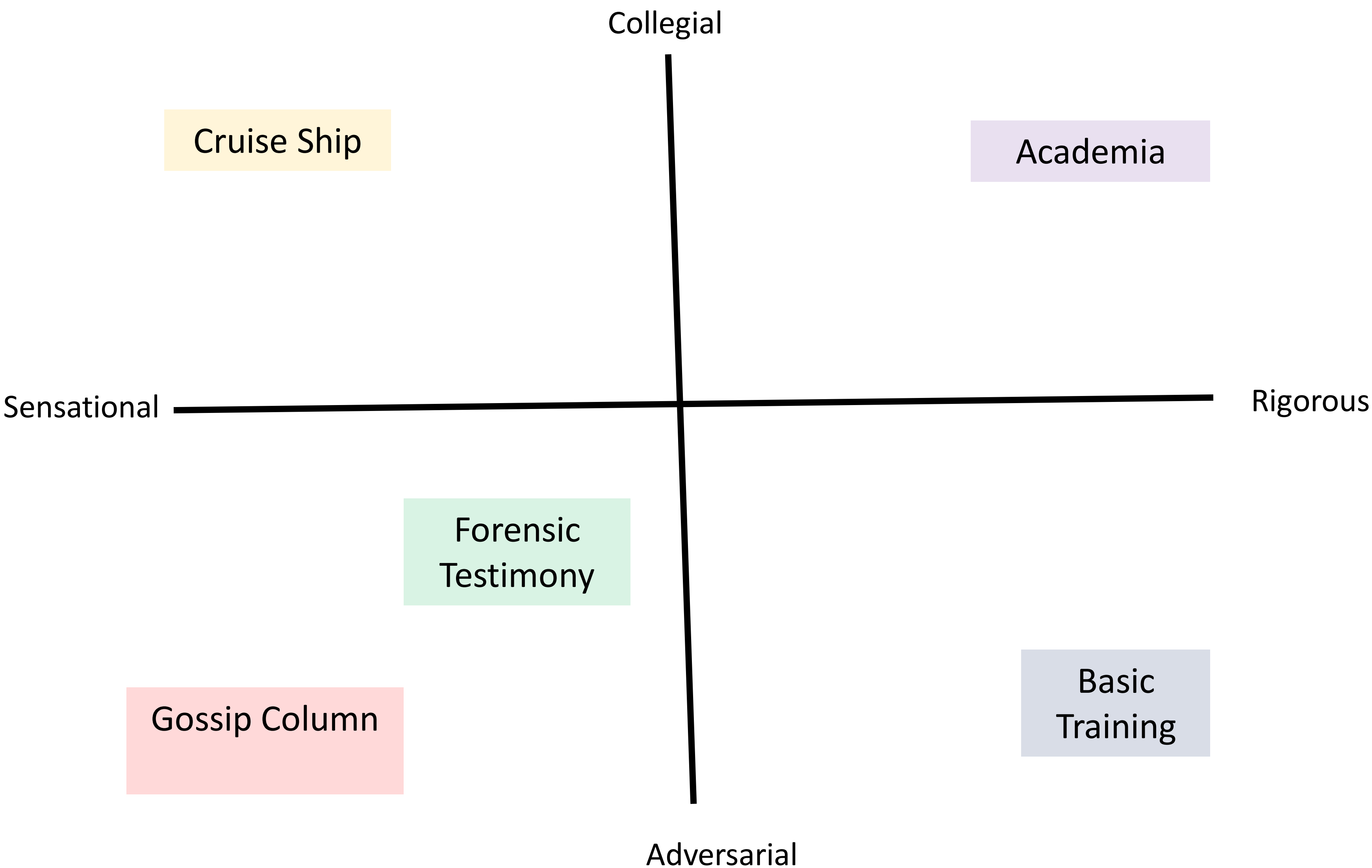
Jeff Salyards, PhD, MFS
Executive Director
Defense Forensic Science Center

Forensic Science vs Physical Science

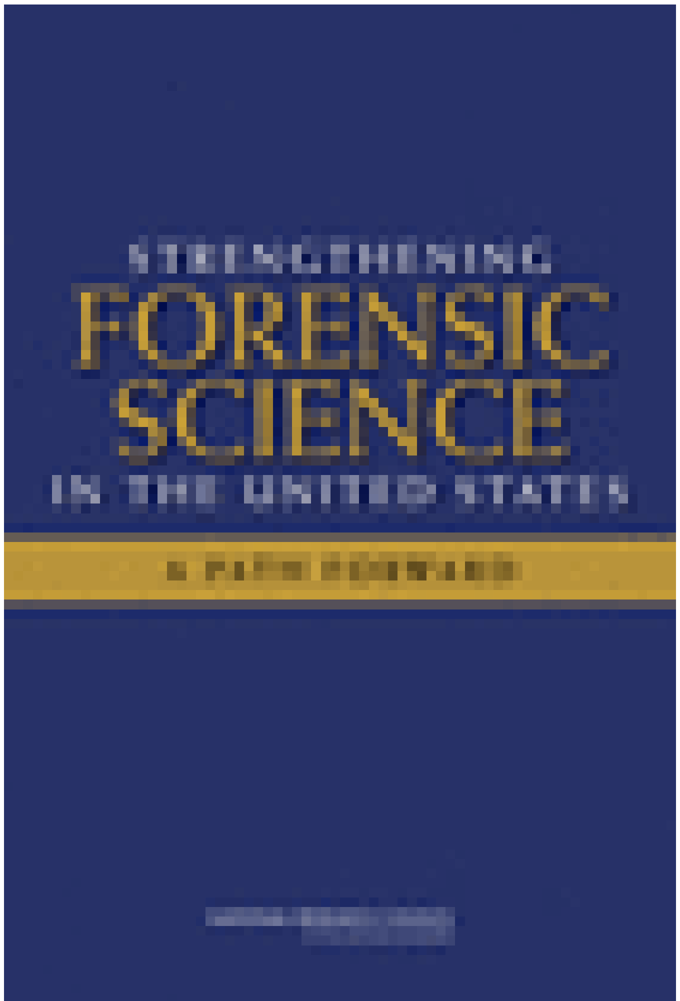
- Create a historic narrative
- Must be communicated & accepted in a non-scientific environment
- Emotionally charged practice

- Make future predictions
- Peer-reviewed communication
- Intellectually laden practice

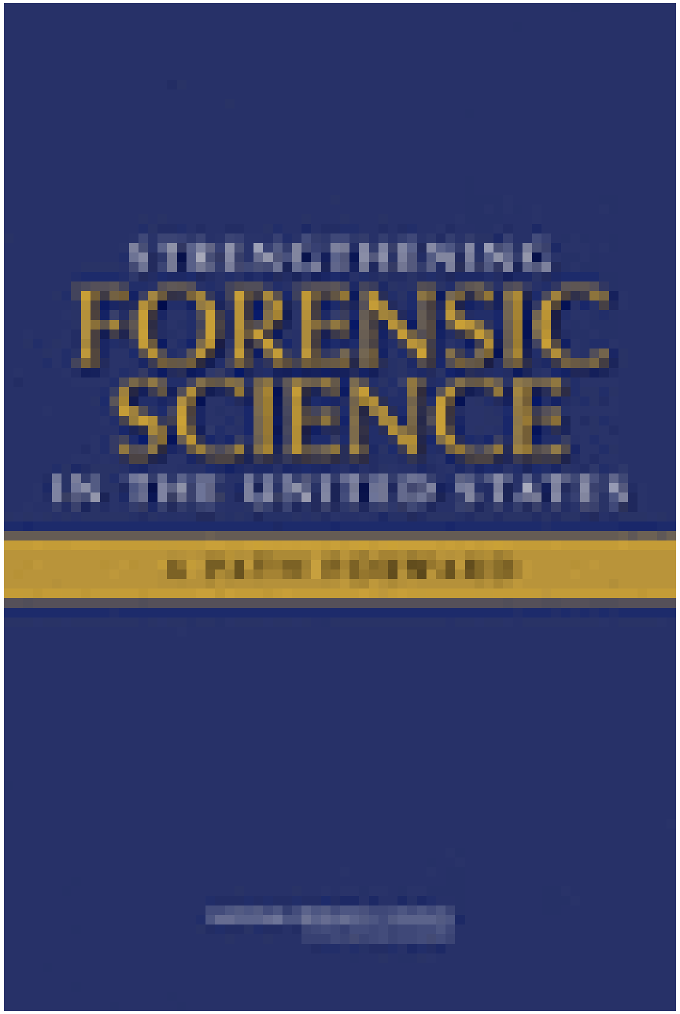
Cultural Considerations



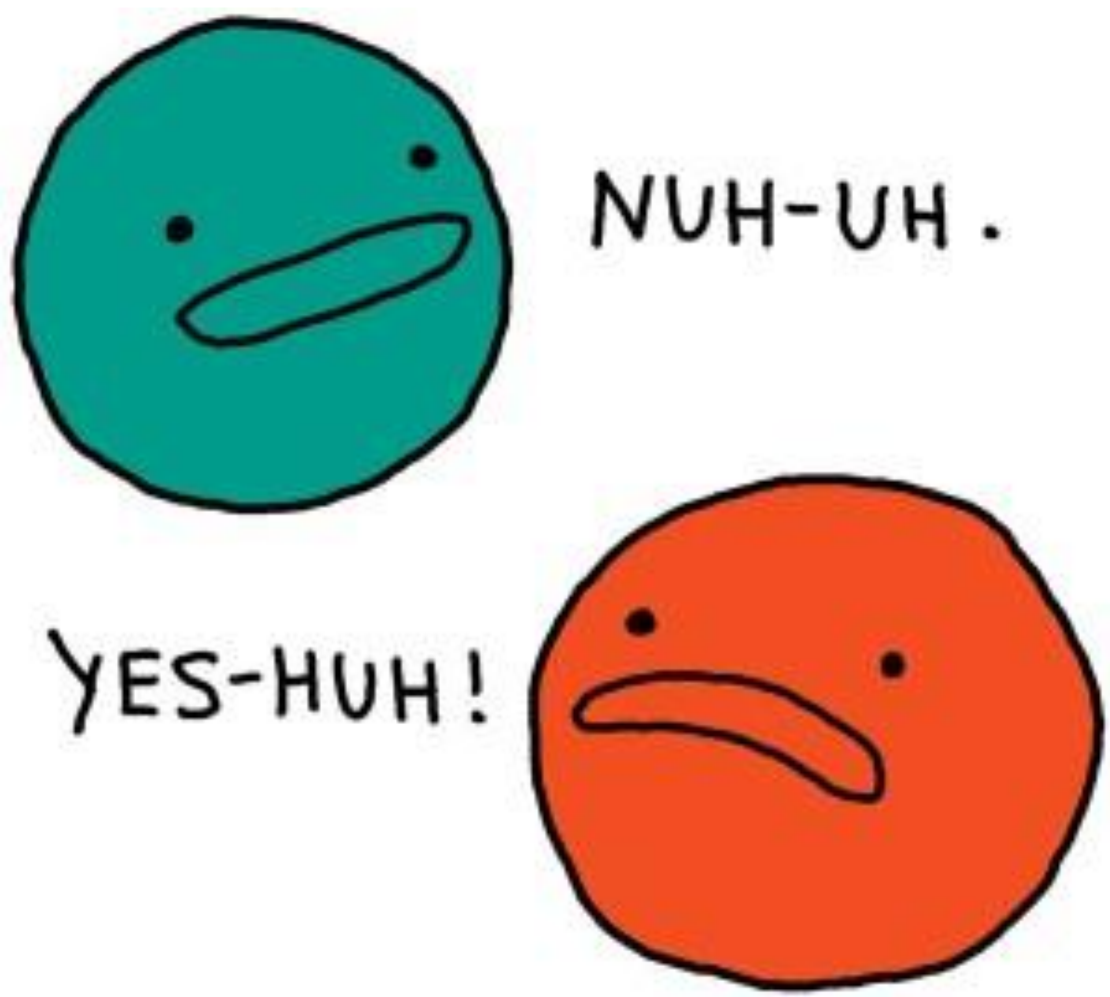
“The” NAS Report



The Literature Search



The Debate -- The 1st 12 Months

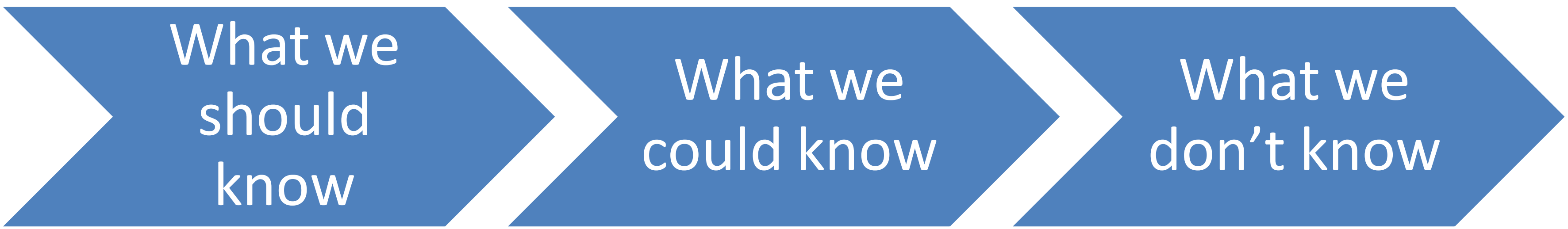


The Assignment

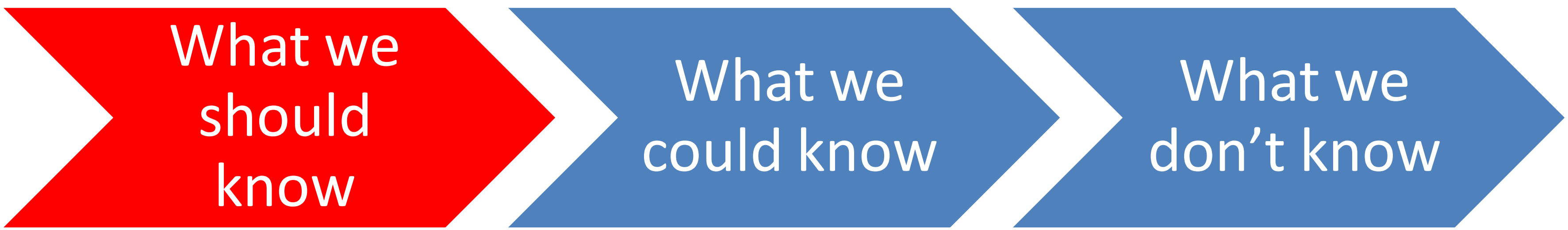
Scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning.

Isaac Newton
"Rules for the study of natural philosophy,"
Philosophiae Naturalis Principia Mathematica

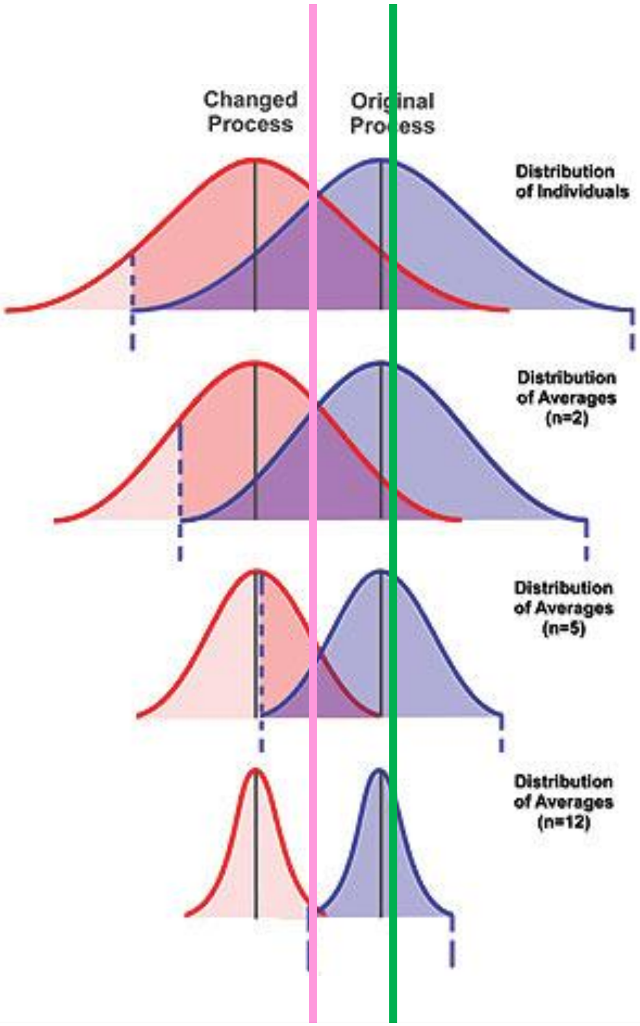
RDT&E Opportunities & Responsibilities

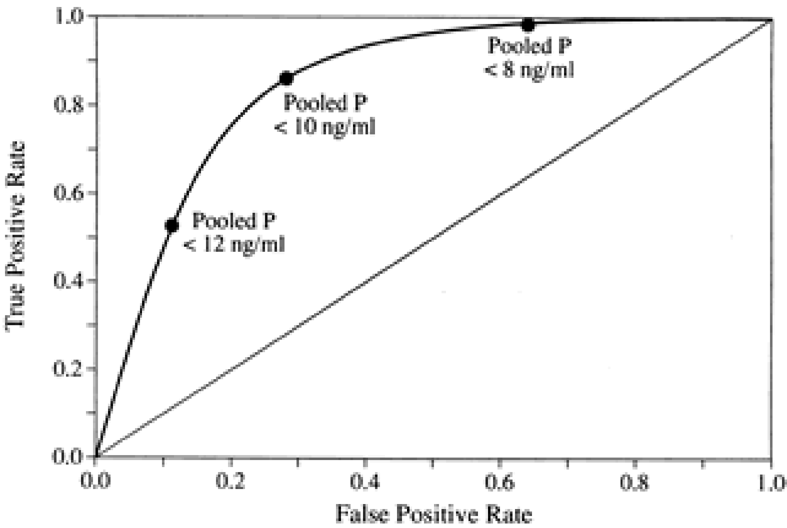


RDT&E Opportunities & Responsibilities



Recommendation 3 – NAS Report





Peer-reviewed research on uncertainty, accuracy and reliability

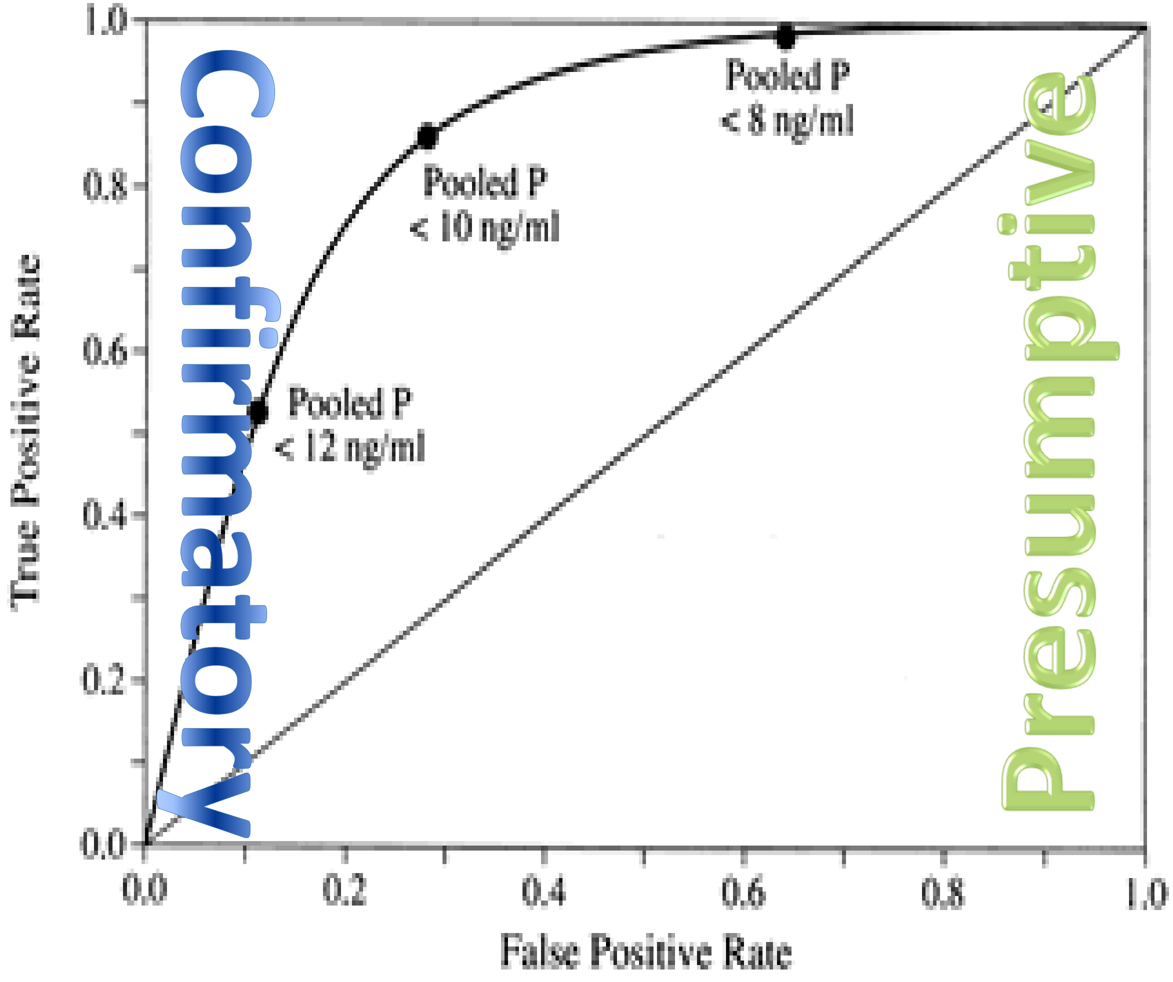
RDT&E Opportunities & Responsibilities

What we should know

What we could know

What we don't know

Words Should Have Meaning



SWGDRUG

SCIENTIFIC WORKING GROUP FOR THE ANALYSIS OF SEIZED DRUGS (SWGDRUG) RECOMMENDATIONS

RECOMMENDATIONS INCLUDE:

- CODE OF PROFESSIONAL PRACTICE
- EDUCATION and TRAINING
- METHODS OF ANALYSIS
- QUALITY ASSURANCE

UNITED STATES DEPARTMENT OF JUSTICE
DRUG ENFORCEMENT ADMINISTRATION

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF NATIONAL DRUG CONTROL POLICY
COUNTERDRUG TECHNOLOGY ASSESMENT CENTER

Revision 6, 2011-July-7

PART III B

METHODS OF ANALYSIS/DRUG IDENTIFICATION

1 Introduction

The purpose of PART III B is to recommend minimum standards for the forensic identification of commonly seized drugs. It is recognized that the correct identification of a drug or chemical depends on the use of an analytical scheme based on validated methods (see PART IV B – Validation) and the competence of the analyst. It is expected that, in the absence of unforeseen circumstances, an appropriate analytical scheme effectively results in no uncertainty in reported identifications (see PART IV C – Uncertainty). SWGDRUG requires the use of multiple uncorrelated techniques. It does not discourage the use of any particular method within an analytical scheme and it is accepted that unique requirements in different jurisdictions may dictate the practices followed by a particular laboratory.

2 Categorizing analytical techniques

Techniques for the analysis of drug samples are classified into three categories (see Table 1) based on their maximum potential discriminating power. However, the classification of a technique may be lower, if the sample, analyte or mode of operation diminishes its discriminating power.

Examples of diminished discriminating power may include:

- an infrared spectroscopy technique applied to a mixture which produces a combined spectrum
- a mass spectrometry technique which only produces molecular weight information

Table 1: Categories of Analytical Techniques

Category A	Category B	Category C
Infrared Spectroscopy	Capillary Electrophoresis	Color Tests
Mass Spectrometry	Gas Chromatography	Fluorescence Spectroscopy
Nuclear Magnetic Resonance Spectroscopy	Ion Mobility Spectrometry	Immunoassay
Raman Spectroscopy	Liquid Chromatography	Melting Point
X-ray Diffractometry	Microcrystalline Tests	Ultraviolet Spectroscopy

The "Gold Standard" – DNA

Unrestricted

All combinations of alleles are deemed possible (relative peak height differences are not utilized)

AB + AC + AD + BC + BD + CD

Restricted

Based on relative peak heights, alleles are paired only where specific combinations of alleles are deemed possible

AB + ~~AC~~ + ~~AD~~ + ~~BC~~ + ~~BD~~ + CD

Survey of the Literature – A good, bad idea!

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- Questioned Documents
- Toxicology

QUICK LINKS

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AAFS MISSION

The American Academy of Forensic Sciences is a multi-disciplinary professional organization that provides leadership to advance science and its application to the legal system. The objectives of the Academy are to promote professionalism, integrity, competency, education, foster research, improve practice, and encourage collaboration in the forensic sciences.

SUBSCRIBE TO THE JOURNAL

Article Review – Another good, bad idea!

J. Chem. Sci., Vol. 118, No. 1, January 2006, pp. 23–35. © Indian Academy of Sciences.

Fluorescence resonance energy transfer (FRET) in chemistry and biology: Non-Förster distance dependence of the FRET rate

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Abstract. Fluorescence resonance energy transfer (FRET) is a popular tool to study equilibrium and dynamical properties of polymers and biopolymers in condensed phases and is now widely used in conjunction with single molecule spectroscopy. In the data analysis, one usually employs the Förster expression which predicts ($1/R^6$) distance dependence of the energy transfer rate. However, critical analysis shows that this expression can be of rather limited validity in many cases. We demonstrate this by explicitly considering a donor–acceptor system, polyfluorene (PF_6)-tetraphenylporphyrin (TPP), where the size of both donor and acceptor is comparable to the distance separating them. In such cases, one may expect much weaker distance (as $1/R^2$ or even weaker) dependence. We have also considered the case of energy transfer from a dye to a nanoparticle. Here we find $1/R^4$ distance dependence at large separations, completely different from Förster. We also discuss recent application of FRET to study polymer conformational dynamics.

Keywords. Fluorescence resonance energy transfer (FRET); non-Förster regime; single molecule spectroscopy; donor–acceptor system.

1. Introduction

Resonance energy transfer (RET) is a widely prevalent photophysical process through which an electronically excited 'donor' molecule transfers its excitation energy to an 'acceptor' molecule (as depicted in figure 1) such that the excited state lifetime of the donor decreases.[1,2] If the donor happens to be a fluorescent molecule RET is referred to as fluorescence resonance energy transfer, FRET. The acceptor however may or may not be fluorescent.

Solving the enigma surrounding fluorescence quenching experiments revealed the phenomenon of FRET and led J Perrin[3] to propose dipole–dipole interactions as the mechanism via which molecules can interact without collisions at distances greater than their molecular diameters. Some 20 years later, Förster[1] built upon Perrin's idea to put forward an elegant theory which provided a quantitative explanation for the non-radiative energy transfer in terms of his famous expression given by

$$k_F = k_{rad}(R_F/R)^6, \qquad (1)$$

where k_{rad} is the radiative rate (typically less than 10^9 s^{-1}) and R_F is the well-known Förster radius given by the spectral overlap between the fluorescence spectrum of the donor and the absorption spectrum of the acceptor. Since then the technique of FRET has come a long way finding applications in most of the disciplines, which by itself signifies the importance of Förster's formulation and usefulness of this technique.

Undoubtedly, understanding any phenomenon on a molecular scale has always been one of the major goals of all physical, chemical and biological quests. However, at present when there is great interest in characterizing nano-materials, its achievement has gained immense priority as never before. To understand a phenomenon on a molecular scale requires information about the spatial relationships between the molecules, and this is where FRET's performance is the best, i.e. to quantitatively measure distances between molecules in the range of 10–100 Å, thereby providing us with invaluable information about structures and dynamics of macromolecules.

In this paper, we shall address several aspects of FRET. The emphasis of this paper is on the distance-dependence of the fluorescence energy transfer. Recent studies have shown that the usually accepted R^{-6} distance dependence can be easily violated when the

Dedicated to Prof J Gopalakrishnan on his 62nd birthday
*For correspondence

Annotated Bibliographies – The real good idea!

Foundational Forensic Science Annotated Bibliographies

Overview

In response to the 2009 NAS report on Forensic Science, a federal, state and local interagency initiative was established to explore policies, procedures and plans related to forensic science in the criminal justice and medical examiner/coroner systems. In support of this initiative, a specific effort was identified to delve into issues related to forensic science research, development, testing & evaluation. A key activity of this work included the assemblage of existing foundational forensic science research in the form of annotated bibliographies. This information was organized by discipline and submitted on behalf of a professional organization or other entity such as a Scientific Working Group (SWG) which represents a specific forensic science discipline. The bibliographic information was submitted by external entities and has not undergone review or analysis, and is not recommended or endorsed by the federal government. It is provided on this website as a reference for interested stakeholders for informational purposes only.

Forensic Science Disciplines

1. Firearms & Toolmarks Analysis

The annotated bibliography was a joint submission by the Association of Firearm and Tool Mark Examiners (AFTE) and Scientific Working Group for Firearms and Toolmarks (SWGGUN) received on June 14, 2011. Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/Joint_AFTE_and_SWGGUN_Annotated_Bibliography_Response_6.14.11.pdf

2. Handwriting Analysis

The annotated bibliography is pending submission by the Scientific Working Group for Forensic Document Examination (SWGDOC). Once available, it will be posted on this website.

3. Bitemark Analysis

The annotated bibliography was submitted on October 2, 2011, by the American Board of Forensic Odontology (ABFO). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/ABFO_Submission_-_approved_ABFO_EC_10-1-2011.pdf

4. Hair Analysis

The annotated bibliography was submitted on September 21, 2012, by the Scientific Working Group for Materials Analysis (SWGMAT). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/SWGMAT-Hair_Annotated_Bibliography_Response_generated_5-3-12.pdf

5. Fiber Analysis

The annotated bibliography was submitted on October 18, 2011, by the Scientific Working Group for Materials Analysis (SWGMAT). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/SWGMAT-Fiber_Annotated_Bibliography_Response_10-18-2011.pdf

6. Latent Print Analysis

The annotated bibliography was submitted on November 17, 2011, by the Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/SWGFAST_Annotated_Bibliography_Response_11-17-2011.pdf

7. Bloodstain Pattern Analysis

The annotated bibliography was submitted on September 29, 2011, by the Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/SWGSTAIN_Annotated_Bibliography_Response_9-29-2011.pdf

8. Shoeprint & Tire Tread Analysis

The annotated bibliography was submitted on November 16, 2011, by the Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/SWGTREAD_Annotated_Bibliography_Response_11-16-2011.pdf

9. Paint & Other Coatings Analysis

The annotated bibliography was submitted on September 21, 2012, by the Scientific Working Group for Materials Analysis (SWGMAT). Please use the following link to access the annotated bibliography: http://collaborate.nist.gov/twiki-fs/pub/ForensicScience/ResearchDevelopment/SWGMAT-Paint_Annotated_Bibliography_Response_generated_041412.pdf

Annotated Bibliography – Hair Analysis

RDT&E IWG Hair Analysis Questions

1. What literature exists that addresses the use of mtDNA analysis in conjunction with conventional morphological hair comparisons?

Houck, M. M., Budowle, B. (2002). Correlation of Microscopic and Mitochondrial DNA Hair Comparisons. ***Journal of Forensic Sciences*****, 47, 964-967.**

The authors used data from human hairs submitted to the FBI Laboratory for analysis between 1996 and 2000. Of the 170 microscopical hair examinations, there were 80 associations, and of these, 9 were excluded by mitochondrial DNA (mtDNA) analysis. 66 hairs that were considered either unsuitable for meaningful microscopical analysis or yielded inconclusive microscopic associations provided meaningful mtDNA results. Only 6 hairs did not provide sufficient mtDNA and only 3 yielded inconclusive mtDNA results. Consistency was observed in the exculpatory results between the two procedures. This study demonstrates the utility of microscopical hair examinations and the strength of combining microscopic analysis with mtDNA sequencing.

Bisbing, R. E., Wolner, M. F. (1984). Microscopical Discrimination of Twins' Head Hair. ***Journal of Forensic Sciences*****, 29, 780-786.**

Duplicate head hair samples from 17 pairs of twins and one set of triplets were compared in a blind study. Each hair sample was separated into two mounted slides, each containing 25 hairs. Using macroscopic and microscopic characteristics of the head hairs, the researchers were able to correctly associate the specimens with the duplicate sample and never with a twin. In a second part of the study, simulated forensic comparisons were performed. Seven tests were prepared where questioned hairs were compared to several randomly selected known samples. In this part of the study none of the known pools randomly selected actually contained the corresponding known sample from the questioned hair. In the seven tests, the first examiner correctly excluded 47 out of 52 samples and the second examiner correctly excluded 49 out of 52 samples. Although no DNA testing was conducted on the samples, it should be noted that all of the twins will have the same mitochondrial DNA and all of the identical twins will have the same nuclear DNA.

*It should be noted that throughout this study, the hairs were mounted only between two glass microscope slides. In a full microscopical analysis, the hairs would be mounted in a mounting media which allows for greater resolution of the microscopic characteristics.

Linch, C. A., Smith, S. L., Prahlow, J. A. (1998). Evaluation of the human hair root for DNA typing subsequent to microscopic comparison. ***Journal of Forensic Sciences*****, 43, 305-314.**

Linch, C. A., Whiting, D. A., Holland, M. M. (2001). Human hair histogenesis for the mitochondrial DNA forensic scientist. ***Journal of Forensic Sciences*****, 46, 844-853.**

Melton, T., Dimick, G., Higgins, B., Lindstrom, L., Nelson, K. (2005). Forensic Mitochondrial DNA analysis of 691 casework hairs. ***Journal of Forensic Sciences*****, 50, 73-80.**

Roberts, K.A., Calloway, C. (2007). Mitochondrial DNA amplification success rate as a function of hair morphology. ***Journal of Forensic Sciences*****, 52, 40-47.**

Sekiguchi, K., Hajime Sato, Kasai, K. (2004). Mitochondrial DNA heteroplasmy among hairs from single individuals.

2. What literature exists that evaluates and reports on the investigative value of hair evidence and the types of questions that can be answered by microscopic hair comparisons?

Robertson, J. (1999). Forensic Examination of Hairs. London: Taylor and Francis.

This text book covers aspects of hair examination including the microscopical comparison of hairs. Other chapters in this text include the growth and morphology of human hair, DNA derived from hairs, elemental analysis of hair, drug analysis using hair, cosmetic treatment that can be performed on hairs and finally a chapter on the evidential value of hair examinations.

Bisbing R. E. (2002). Forensic Science Handbook Volume 1 2nd Edition: Chapter 7 – The Forensic Identification and Association of Human Hair. Edited by Saferstein, R., New Jersey: Prentice-Hall Inc.

This text has chapters on many fields of forensic science. The chapter on human hair identification and association includes topics on hair structure, growth, identification and comparison, collection, conclusions and report writing and presentation of the evidence in court.

Hicks, J. W. (1977). Microscopy of Hairs: A Practical Guide and Manual. Issue 2. Washington, DC: Federal Bureau of Investigation.

Deedrick, D., Koch, S. L. (2004). Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs. Quantico, VA: Federal Bureau of Investigation.

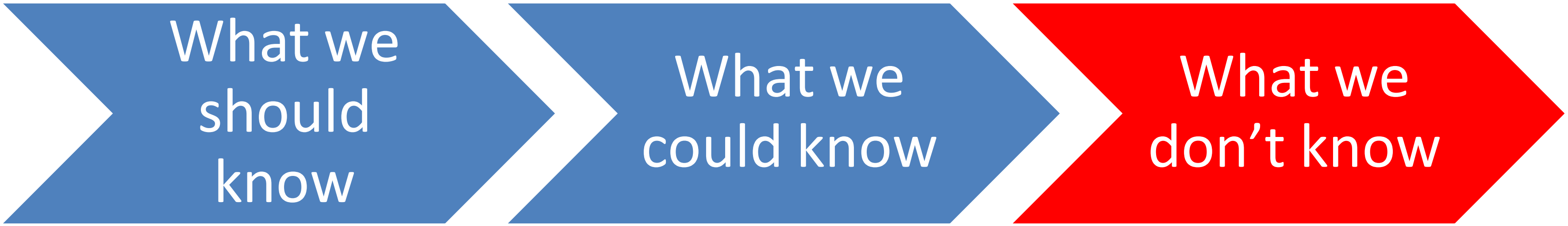
In an introductory guide to forensic hair examinations, the author details the characteristics observed between the different races and the different body areas. Also detailed in the guide is the basic structure of hair and the characteristics that are found useful when performing microscopical hair comparisons.

Deadman, H. A. (1985). Human hair comparisons based on microscopic characteristics. ***Proceedings of the International Symposium on Forensic Hair Comparisons*****, 45-49.**

"Grading" of Annotated Bibliographies

- Proposal
  - Describe approach to reviewing the articles
  - Composition of team members
  - Criteria for assessing scientific merit
  - Venue for the review process
  - Cost
  - Schedule
  - Potential risks
- Deliverables
  - An evaluation of the scientific foundation of the _________________ forensic science discipline.
  - A roadmap of suggested research projects that will best address the identified gaps and needs.

RDT&E Opportunities & Responsibilities



The Future

- Next Generation DNA Sequencing
- Phenotypic Information
- Identification of Body Fluids
- Aging of traditional forensic materials (e.g., when was the fingerprint deposited; what is the PMI ± minutes?).
- Physical science measurements replace qualitative judgments

Challenges & Way-Ahead

- Examiner Participation
- Portfolio vs Program Management
- Appropriate Delivery and Use of Results

RDT&E Summary, Challenges, and Way-Ahead

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