NIST Technical Colloquium on **Quantifying the Weight of Forensic Evidence**
May 5, 2016
Gaithersburg, MD

NIST FORENSIC SCIENCES

Image from Professor Colin Aitken

http://www.ed.ac.uk/polopoly_fs/1.165056!/fileManager/statistical-crime-fighters-2.jpg

Perspectives and Challenges from NIST Involvement in Forensic Science

John M. Butler, Ph.D.

NIST Fellow & Special Assistant to the Director
for Forensic Science

Topics to Cover

- NIST involvement in forensic science
- Early forensic history of NBS/NIST
- Challenges faced & some urban legends
- DNA challenges
- Thoughts on potential improvements
- Lessons from history

Standard NIST Disclaimer

Points of view are mine and do not necessarily represent the official position or policies of the US Department of Justice or the National Institute of Standards and Technology.

Certain commercial equipment, instrum
materials are identified in orde
experimental procedure
possible. In no ca n imply a
recommend ne National
Institu ology nor does it
rials, instruments or
are necessarily the best
e purpose.

I am from the U.S. government and I am here to help you…

Acknowledgments and Disclaimers

I will quote from my recent book entitled "Advanced Topics in Forensic DNA Typing: Interpretation" (Elsevier, 2015). I do not receive any royalties for this book. Completing this book was part of my job at NIST.

I have been fortunate to have had discussions with numerous scientists on DNA interpretation issues including Mike Coble, Bruce Heidebrecht, Robin Cotton, Charlotte Word, Catherine Grgicak, Todd Bille, Peter Gill, Ian Evett, John Buckleton …

Thanks to those who provided input on the Urban Legend ideas: Reva Schwartz, Elham Tabassi, Robert Thompson, Susan Ballou, Melissa Taylor, …

Souder research: Kristen Frederick-Frost and Robert Thompson

My Background → influences my perspective

- I developed an early interest in forensic science and research before the CSI TV shows!
  - Largely from enjoyment of puzzle solving (e.g., Rubik's cube) and reading Sherlock Holmes; took four years of biology in high school
- Did my PhD research (UVA analytical chemistry degree) at the FBI Laboratory's Forensic Science Research Unit (1993-1995)
  - Pioneered modern forensic DNA testing with short tandem repeat (STR) markers and capillary electrophoresis (CE)
- Came to NIST as an NRC postdoc in 1995, left to work in a Silicon Valley biotech startup in 1997, and returned to NIST in 1999 to lead the forensic DNA team (now the Applied Genetics Group)
  - Developed the STRBase website and have written five textbooks on forensic DNA typing and >150 articles (primarily on methodology issues); **interpretation of evidence has became a recent passion (2010 to present) largely from what I learned in writing my last two books**
- In April 2013, I left the NIST lab and moved to the Special Program Office to help with the overall NIST efforts in forensic science
  - **My interests now range well beyond just DNA…**

NIST Involvement in Forensic Science

Why?

Why is NIST involved in forensic science?

- **Our assistance and technical expertise was requested by DOJ and others**
  - Establishment of FBI Laboratory (early 1930s)
  - Automated fingerprint detection (1960s to present)
  - Law Enforcement Standards Laboratory (established in 1971)
  - **"Starch Wars" (1977 to 1978)**
  - Input on TWGDAM/SWGDAM (1988 to present)
  - DNA reference materials (early 1990s to present)
  - **FBI's DNA Advisory Board (1995 to 2000)**
  - Digital forensics (late 1990s to present)
  - National Institute of Justice (NIJ) funding (1970s to present)
  - White House Subcommittee on Forensic Science (2009-2012)
  - MOU leading to NCFS and OSAC (2013-present)

The “Starch Wars” Led to NBS/NIST Involvement in Forensic DNA Efforts

Forensic Science Review
(Jan 2006) 18(1): 59-72

The “Starch Wars” and the Early History of DNA Profiling

J. D. Aronson
Department of History
Carnegie Mellon University
Pittsburgh, Pennsylvania
United States of America

- **Dennis Reeder (NBS protein gel scientist) asked to investigate**
  - 10 years later asked by FBI to be part of TWGDAM (then 17 years later part of DNA Advisory Board)
  - DNA reference material work started
- Dennis meets John M. Butler at a TWGDAM meeting at the FBI Academy and hires JMB (twice)

Abstract

Just as the movie Star Wars had a prequel, so did the "DNA Wars"-the series of legal, scientific, and personal battles tl… the mi… p… st e… n adequately appreciated in the recent history of forensic science. After reviewing the early history of blood typing, I will describe **the development of the Multi-System approach to blood protein analysis that took place in California from 1977 to 1978**. I will then elucidate the history of the Starch Wars, and demonstrate the ways that they shaped subsequent disputes over DNA evidence, especially in California. I will show that: (a) **many of the forensic scientists, law enforcement officials, and lawyers who became prominent players in the DNA Wars were deeply involved in the court cases involving protein electrophoresis**; and (b) many of the issues that became controversial in the disputes over DNA evidence first emerged in the Starch Wars. In the conclusion, I will suggest various ways to improve the quality of forensic science based on my analysis of the Starch Wars.

Mark Stolorow, who came to NIST in 2008 from industry and now leads the NIST OSAC Affairs Office, was one of the developers of the Multi-System almost 40 years ago and involved in those early court battles…

DNA Identification Act (1994)

Public Law 103-322

42 § 14131. Quality assurance and proficiency testing standards

(a) Publication of quality assurance and proficiency testing standards

(1) (A) Not later than 180 days after September 13, 1994, the Director of the Federal Bureau of Investigation shall appoint an advisory board on DNA quality assurance methods from among nominations proposed by the head of the National Academy of Sciences and professional societies of crime laboratory officials.

(B) The advisory board shall include as members scientists from State, local, and private forensic laboratories, molecular geneticists and population geneticists not affiliated with a forensic laboratory, and **a representative from the National Institute of Standards and Technology.**

(C) **The advisory board shall develop, and if appropriate, periodically revise, recommended standards for quality assurance**, including standards for testing the proficiency of forensic laboratories, and forensic analysts, in conducting analyses of DNA.

DNA Advisory Board (DAB)

DNA Advisory Board (DAB) Members

- **Joshua Lederberg** (Rockefeller University) – chair 1995-1998
- **Arthur Eisenberg** (University of North Texas Health Science Center) – chair 1998-2000
- **John Hicks** (Alabama Department of Forensic Sciences)
- **Shirley Abrahamson** (Wisconsin State Supreme Court)
- **Ranajit Chakraborty** (University of Texas Health Science Center)
- **Bruce Budowle** (FBI Laboratory)
- **Larry Presley** (FBI Laboratory)
- **Jack Ballantyne** (Suffolk County Crime Lab)
- **Jay Miller** (FBI Laboratory)
- **Dennis Reeder** (National Institute of Standards and Technology)
- **Margaret Kuo** (Orange County Sheriff's Office)
- **Bernard Devlin** (Carnegie Mellon University)
- **Marcia Eisenberg** (Laboratory Corporation of America)
- **Paul Ferrara** (Virginia Division of Forensic Science)
- **Terry Laber** (Minnesota State DNA Lab)
- Dwight Adams, Randall Murch, Barry Brown (FBI Laboratory)
- David Coffman (Florida Department of Law Enforcement)
- Fred Bieber (Harvard Medical School)
- Mary Gibbons (Oakland Police Department)
- Eric Juengst (Case Western Reserve University)
- Susan Narveson (Phoenix Police Department)
- Mohammad Tahir (Indianapolis-Marion County Crime Lab)
- Dawn Herkenham (FBI Laboratory)

Existed from 1995-2000

This group gave birth to the FBI Quality Assurance Standards (QAS) that are now maintained by SWGDAM (Scientific Working Group on DNA Analysis Methods)

National Institute of Standards and Technology
U.S. Department of Commerce

Co-lead with DOJ

National Commission on Forensic Science

NIST Point-of-Contact (POC): **John Butler**

A federal advisory committee for the U.S. Department of Justice

http://www.justice.gov/ncfs

Organization of Scientific Area Committees

Organization of Scientific Area Committees

POC: **Mark Stolorow & John Paul Jones**

NIST-administered effort dedicated to identifying and developing technically sound, consensus-based documentary standards and guidelines

http://www.nist.gov/forensics/osac/

NIST FORENSIC SCIENCES

NIST Forensic Research Program

NIST Forensic Science Center of Excellence (announced May 2015)

POC: **Sue Ballou**

SIX FOCUS AREAS

1. ***Ballistics and Associated Tool Marks***
2. ***Digital and Identification Forensics***
3. ***Forensic Genetics***
4. ***Toxins***
5. ***Trace***
6. ***Statistics***

http://www.nist.gov/forensics

NIST Forensic Science Center of Excellence (FSCOE)

csafe

Center for Statistics and Applications in Forensic Evidence

IOWA STATE

Pattern Evidence:
In Scope: latent prints, ballistics, tire marks, footwear, handwriting, bloodstain pattern, tool marks.
Out of Scope: voice recognition, face/iris recognition, gunshot residue.

Digital Evidence:
In Scope: computer and information systems, mobile devices, network traffic, social media, GPS.
Out of Scope: Video, surveillance systems, collection or storing of information.

Collaboration focuses on general issues of pattern interpretation:

- Mappings between scores/distances and likelihoods
- How much information comes from models/assumptions that is not present in the data?
- Likelihoods, likelihood ratios, generalized likelihood ratios and Bayes factors
- Relevant populations and the formation of the defense hypothesis
- Probability definitions, utility functions and decision theory
- Information transfer between individuals

Forensic Conference Organized by NIST

Planning has started for a second Symposium
Date: **July 24-28, 2017 (Tentative)**
Location: Washington DC
Sponsors that have been approached
DoD, FBI, NIST

http://www.nist.gov/director/international_forensics_home.cfm

Other Recent Meetings NIST and Partners Have Convened on Forensic Science Topics

1. Forensic firearms analysis (July 2012)
2. DNA mixture interpretation training (Apr 2013)
3. Emerging synthetic drugs (May 2013)
4. Forensic handwriting (June 2013)
5. *DNA Technical Leader Summit (Nov 2013)*
6. Cloud computing forensics (Mar 2014)
7. DNA probabilistic genotyping – Part 1 (May 2014)
8. Mobile forensics (June 2014)
9. DNA validation concepts & resources (Aug 2014)
10. DNA probabilistic genotyping – Part 2 (Sept 2014)
11. Research biometric datasets (Jan 2015)
12. Forensic optical topography (Mar 2015)
13. **Quantifying weight of evidence (May 2016)**

- **OSAC Public Meetings** (Feb 2015 and Feb 2016)
- Forensics@NIST 2010 (NIJ program managers only)
- Forensics@NIST 2012
- Forensics@NIST 2014
- **Forensics@NIST 2016 (Nov 8-9, 2016)**

Webcasting and video archives exist for most of these meetings

http://www.nist.gov/forensics/conferences_and_events.cfm

Early History of NBS/NIST Involvement in Forensic Science

Wilmer Souder's work

Dr. Wilmer Souder and the National Bureau of Standards Identification Laboratory (1935)

AAFS 2016 Presentation

The Best Forensic Scientist You've Never Heard Of

NIST National Institute of Standards and Technology U.S. Department of Commerce

ISO Information Services Office

Kristen M. Frederick-Frost, PhD
Robert M. Thompson, BS
John M. Butler, PhD

NIST FORENSIC SCIENCES

LW1: **Last Word Society**
American Academy of Forensic Sciences
Las Vegas, NV (February 25, 2016)

June 10, 2016
a NIST colloquium presentation will be given on Souder and a NIST museum exhibit opened by his granddaughter

Slides available on the NIST STRBase website:
http://www.cstl.nist.gov/strbase/pub_pres/Souder-AAFS2016-LWS-FINAL.pdf

ANNUAL CONFERENCE

U.S. Secret Service Conference

UNITED STATES SECRET SERVICE

TREASURY DEPARTMENT

January 6, 7, 8, 9, 1941

Fairfax Room Willard Hotel

Washington, D. C.

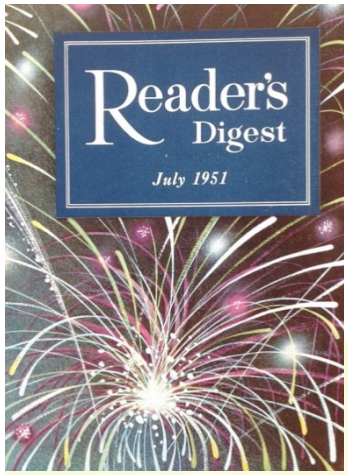
WALTER H. HICKMAN

Stenotype Reporter

Wilmer Souder's Impact in His Day

"This country is indeed fortunate in having a man such as Dr. Souder in his capacity. I think we can look upon him as **the most outstanding expert on the continent in the last one hundred years**."

-Deputy Chief Inspector John J. O'Connell, **New York City Police Department**, after Souder's keynote talk



Reader's Digest July 1951 article

pp. 118-120

When no one else can solve a mystery, Government heads put in a call for Dr. Souder

Washington's Detective X

Condensed from This Week Magazine

Emile C. Schurmacher

Rediscovery of Wilmer Souder's Notebooks

Transferred to NIST Archives in 2003

by Alcohol, Tobacco, Firearms, and Explosives Laboratory

Detailed analysis started in May 2015

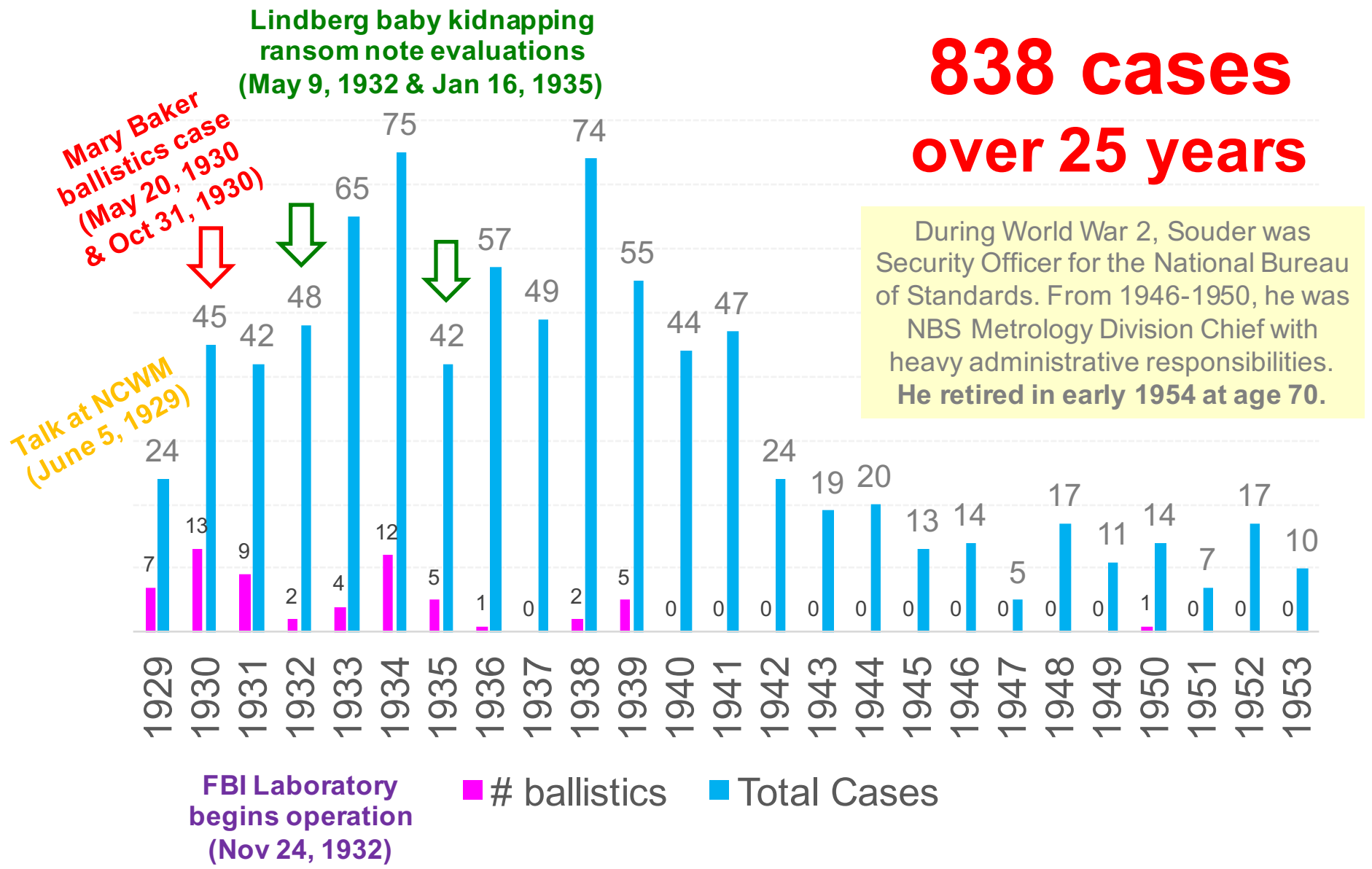
Content of Souder Notebook Entries

- Date for Evidence Submission
- NBS Test Number
- Submitting Agency
- Submitting Agent
- Summary of Findings
- Disposition of evidence (chain-of-custody)
- Case court outcome if known
- Newspaper Clippings from cases

NBS: National Bureau of Standards (name changed to NIST in 1988)

Number of Cases Worked by Wilmer Souder

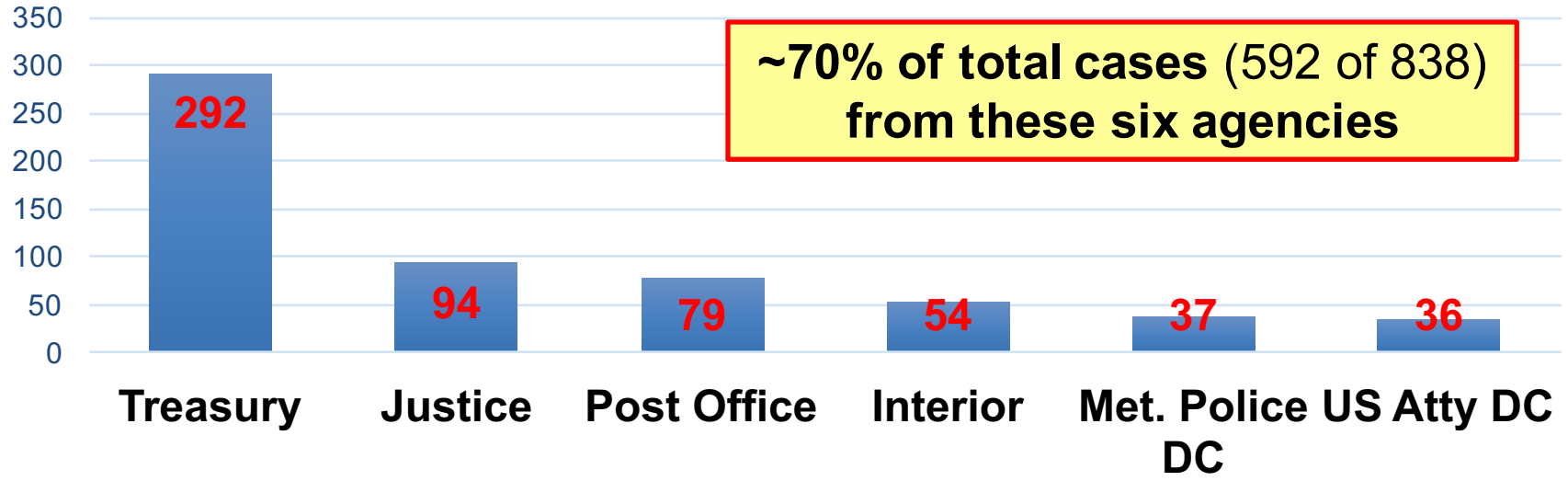
based on entries in his notebooks



Submitting Agencies

(Handwriting, Typewriting, and Ballistics Casework)

Total Number of Cases Submitted (1929-1953)



~70% of total cases (592 of 838) **from these six agencies**

Remaining 30% of cases were from >75 additional agencies including:

Census Bureau
Civil Service
Department of Agriculture
Department of Commerce
House of Representatives
Library of Congress
Senate Judiciary Committee
State Department

DC Health Department
DC Office of Weights & Measures
DC Supreme Court
National Labor Relations Board
New York Police Department
Office of Civil Defense
Patent Office
Security & Exchange Commission

Bureau of Prisons
Federal Housing Admin.
Federal Trade Commission
General Accounting Office
Government Printing Office
Military Intelligence Division
US Secret Service
War Department

Early NBS/NIST – FBI Connection

Studied chemistry at the University of Chicago and graduated in 1917

Charles' older brother

William D. Appel

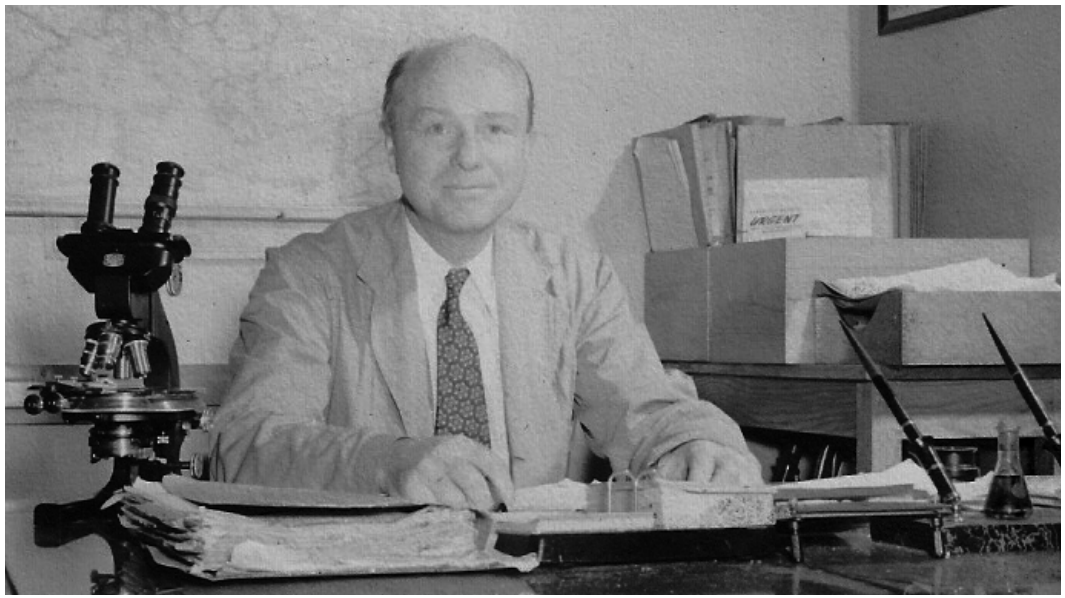
(NBS: 1922-1959)

Wilmer Souder, on leave from NBS, received a PhD in physics at the University of Chicago and graduated in 1916 but stayed to teach courses in physics and chemistry until 1917

First employee of FBI Technical Laboratory

Charles A. Appel, Jr.

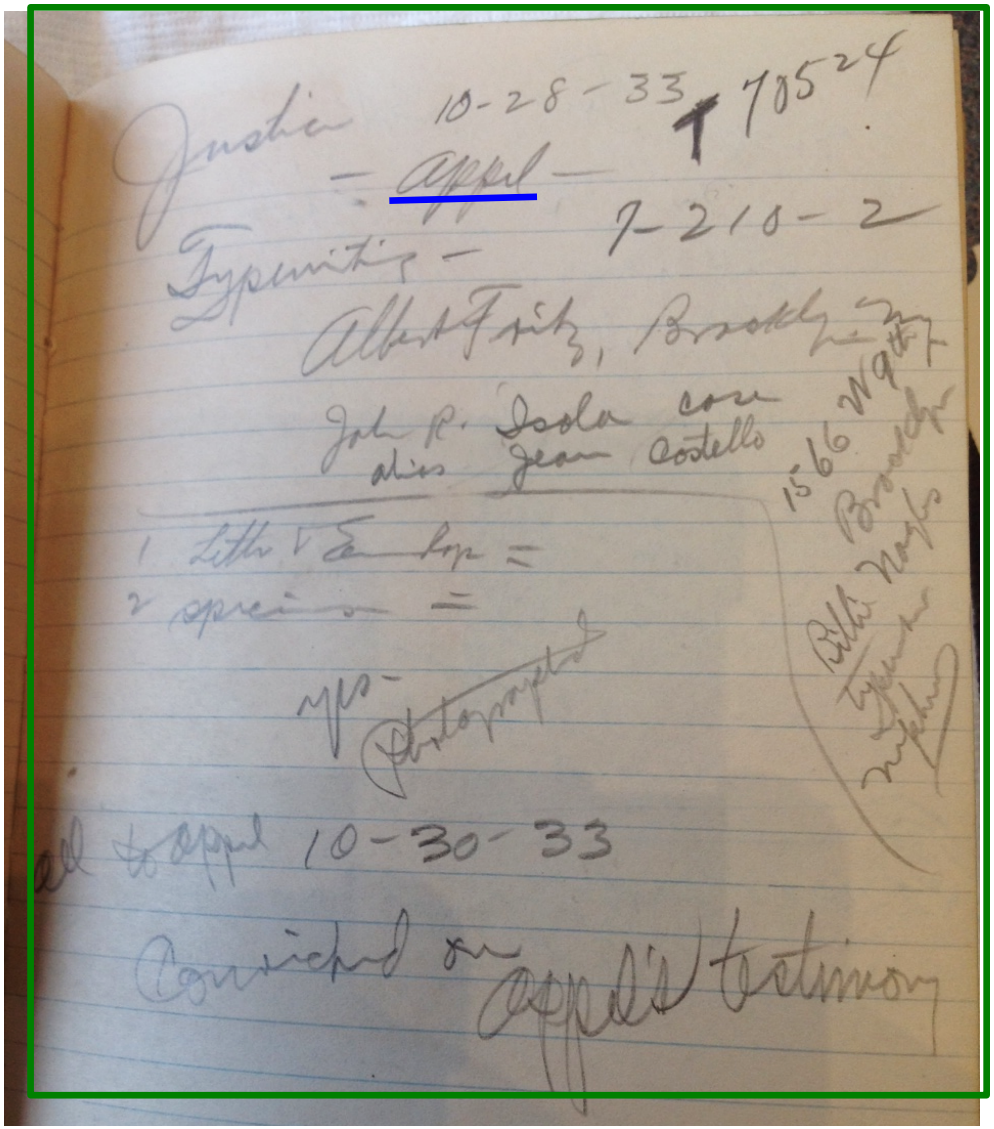
(FBI: 1924-1948)



1942 photo of Special Agent Charles Appel (courtesy of his son Ed Appel)

Conducting Casework in the Background…

A page from one of Wilmer Souder's notebooks (rediscovered June 2015)



Typewriting casework received from the Department of **Justice** – Charles **Appel** (first FBI Laboratory employee) on October 28, 1933 (10-28-33)

All [material returned] **to Appel** on October 30, 1933 (10-30-33)

Convicted on Appel's testimony

Souder's Assistance to the FBI Recognized

Letters from FBI Director J. Edgar Hoover to NBS Directors Burgess and Briggs

Official Start Date for the FBI Laboratory: November 24, 1932

November 10, 1931

U. S. Department of Justice
Bureau of Investigation
Washington, D. C.

TO CENTRAL FILES, DATE
CHARGE NO
November 10, 1931.
YES | NO
BRIEFED
USELESS PAPER
SAC, RM. ADVISED
LIBRARY ADVD
VIA TEST CLERK

II-6 WS
II-6/IWE-402-C

Dr. George R. Burgess,
Bureau of Standards,
Washington, D. C.

Dear Dr. Burgess:

I desire to express to you and your organization my appreciation for your splendid cooperation with this Bureau in the recent investigation and trial of Abner Siegal, local attorney.

Your interest and the work performed by Dr. Wilmer Souder, was, in my opinion, largely responsible for the conviction of this defendant.

Sincerely yours,

J. Edgar Hoover
Director.

Conducting Casework

March 19, 1934

JOHN EDGAR HOOVER
DIRECTOR

Division of Investigation
U. S. Department of Justice
Washington, D. C.
March 19, 1934

D WS
II-6/IWE-402-C

Dr. Lyman J. Briggs,
Director, Bureau of Standards,
Department of Commerce,
Washington, D. C.

Dear Dr. Briggs:

I have just received information from one of my assistants in charge of the Division's training school to the effect that Dr. Wilmer Souder appeared before the trainees and gave a most valuable lecture on firearms and document identification.

J.A.S.

It is a source of great pleasure to me to receive reports of this character from my assistants, and I want to take this occasion to express my appreciation to you for your most helpful cooperation in allowing Dr. Wilmer Souder to appear before these classes.

I sincerely trust that if the Division can be of any assistance to you in matters of mutual interest you will not hesitate to communicate with me.

With expressions of my high esteem and best personal regards, I am

Sincerely yours,

J. Edgar Hoover
Director.

Providing Training

FBI Laboratory Began Operations

November 24, 1932 with Assistance of Dr. Wilmer Souder

Page 47: "**The development of the [FBI] Laboratory has been carefully planned by the Division with the assistance and advice of Dr. Wilmer Souder**, a well-known and recognized authority in the field of scientific endeavor. Dr. Souder, who is at present acting in an advisory capacity in the further development of the Laboratory, has been engaged as a scientist by the Bureau of Standards for a period of eighteen years and has devoted the principle portion of his time to handwriting, typewriting and ballistics identification. **His advice and experience have rendered invaluable service to the Division in the training of the Laboratory personnel and in obtaining equipment which is considered the most desirable and essential for the performance of its work**."

From "A Digest of the Early History of the FBI Laboratory" (prepared by Fred M. Miller January 1956 for use by Don Whitehead in writing Chapter 16 of his 1956 book *The FBI Story*); a copy provided to NIST by FBI Historian John Fox on July 9, 2015

Challenges Faced in Forensic Science

…and some Urban Legends

Slide presented in September 2013 to a White House-led Federal Working Group on Forensic Research

Some Significant Needs in Forensic Science

More critical thinking is needed in forensic science at the bench level and in management

Problem	Needs and NIST Efforts
More advanced methods for DNA mixture interpretation	DNA Technical Leader Summit *(planned for Nov 2013)*
Growth in mobile & computer forensic needs	Continue work to collect comprehensive software set
Keeping up with emerging synthetic drugs	Reference materials, mass spectral libraries, IR spectra prediction
Quantitative fingerprint evaluations	Large data sets needed for fingerprints and other pattern matching disciplines to train new matching algorithms

Important Observations

- The National Research Council 2009 (**"NAS Report"**) **called for changes** to strengthen forensic science (with 13 recommendations) but these are not really new issues

- **The criminal justice system**, where forensic science only plays a small part, **is not perfect**; there have been individuals wrongly convicted for a variety of reasons

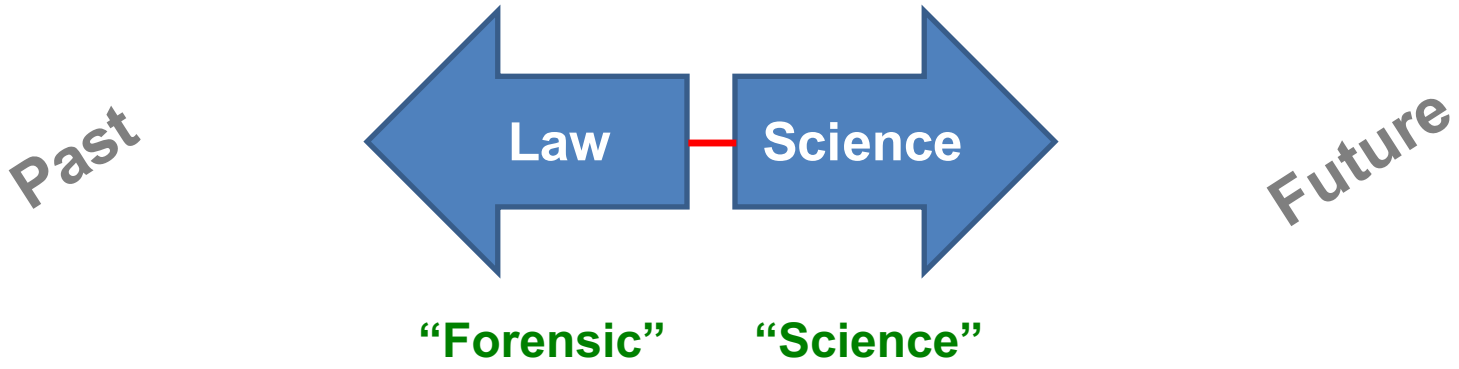
- Despite a few well-publicized examples (e.g., Annie Dookhan), **forensic scientists** generally want to do a good job and **are trying to do their best**

- **Many forces are at play** to either change things or to maintain the status quo → ***which changes are needed?***

Culture Clash: Science and Law

Tension exists between science and the law:

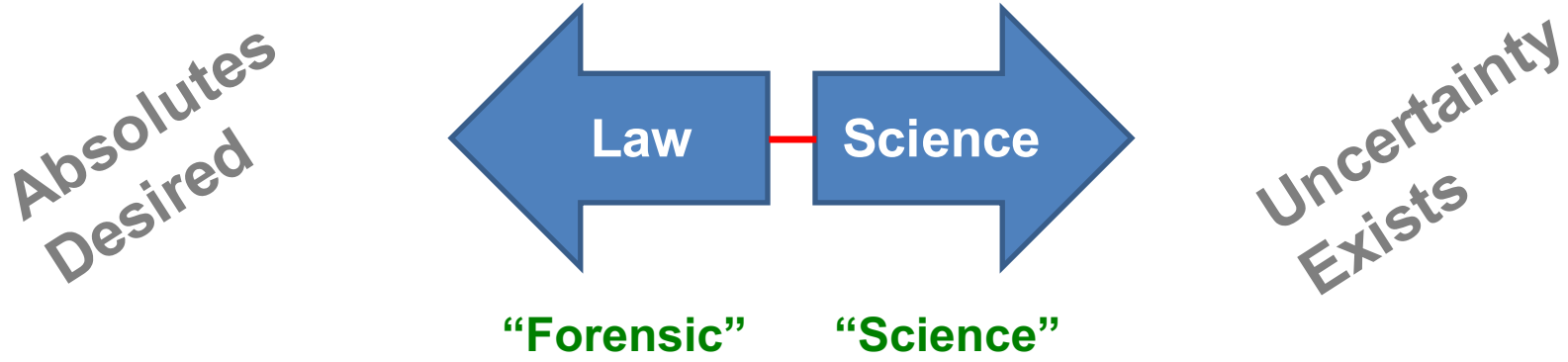
- The legal community **looks to the past** (precedence is desired)
- The scientific community **looks to the future** (evolving improvement is desired)



Culture Clash: Science and Law

Tension exists between science and the law:

- The legal community **wants finality and absolutes** (guilty or not-guilty court decisions)
- The scientific community **operates without certainty** (rarely with probabilities of 0 or 1)



Nomenclature Challenges

- We often talk past each other (scientists and lawyers or scientists and scientists) because we do not appreciate a subtle or significant difference in the meaning of a word or phrase

- Examples: “validity” or “validation” can mean something very different to lawyers than to scientists and forensic practitioners

- “A reasonable degree of scientific certainty…” (a legal crutch that has no scientific meaning)

Different Statistical Approaches Exist

Bayesian approach

Combines LR with prior odds (or prior probability)

Likelihood Ratio (LR)

Bayes' Theorem

$$\text{Prior Odds} \times \frac{\Pr(E \mid H_1)}{\Pr(E \mid H_2)} = \text{Posterior Odds}$$

Frequentist approach

Considers only a single hypothesis (e.g., $\Pr(E|H_2)$ = profile probability) or the LR involving two mutually exclusive hypotheses

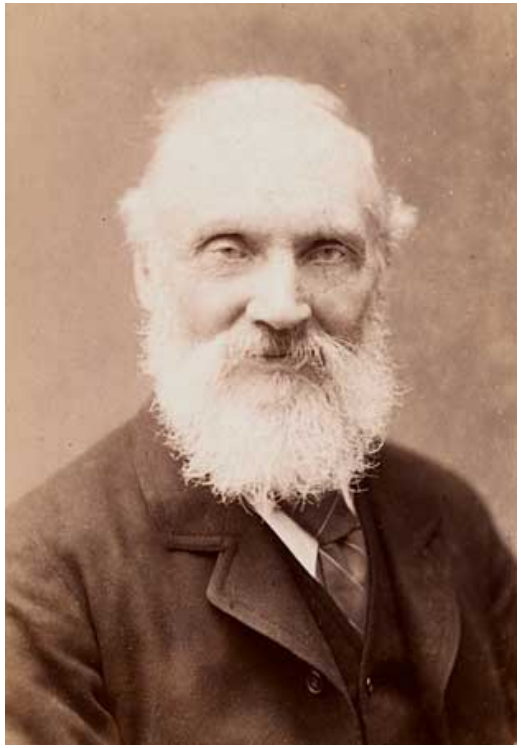
Figure 9.2 from J.M. Butler (2015) *Advanced Topics in Forensic DNA: Interpretation* (Elsevier Academic Press: San Diego)

Data Quality Issues

- Forensic samples often involve working with a partial data pattern
  - In DNA, not doing the entire genome and sometimes not even the entire attempted profile
  - In latent prints, typically not looking at the entire print

- A theoretical model may not fit casework data…
  - George Box: “All models are wrong – but some are useful”

William Thomson, 1st Baron Kelvin, aka Lord Kelvin



http://digital.nls.uk/scientists/assets/images/content/lord_kelvin/lord-kelvin.jpg

- "**When you can measure what you are speaking about, and express it in numbers, you know something about it**, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts advanced to the stage of science."

- "There cannot be a greater mistake than that of looking superciliously upon practical applications of science. **The life and soul of science is its practical application**..." [PLA, vol. 1, "Electrical Units of Measurement", May 3, 1883]

Slide courtesy of Rich Cavanagh (NIST Special Programs Office)

NIST Efforts are usually in Pasteur's Quadrant

Donald E. Stokes, ***Pasteur's Quadrant – Basic Science and Technological Innovation*****, Brookings Institution Press, 1997.**

		Applied and Basic research	
Quest for fundamental understanding?	**Yes**	Pure basic research (**Bohr**)	Use-inspired basic research (**Pasteur**)
	No	**Lawyers**	Pure applied research (**Edison**)
		No	**Yes**
		Considerations of use?	

Slide courtesy of Rich Cavanagh (NIST Special Programs Office)

Another Culture Clash

A "**Liberal**" perspective towards scientific principles

A "**Conservative**" perspective towards scientific principles

"Protocol Protection"

"Protocol Perfection"

Forensic Practitioners ⇢

⇠ **NIST Scientists & Statisticians**

***Learning is taking place on both sides**, but in the end some compromise will be required to move forward*

Urban Legend

- a modern story of obscure origin and with little or no supporting evidence that spreads spontaneously in varying forms and often has elements of humor, moralizing, or horror (dictionary.com)

Top Ten… Urban Legends of Forensic Science

10. I do my work the same every time – why do I need to write down my method and results?

9. More money will solve all of our problems

8. I am not “biased” (and what does “bias” mean anyway?)

Top Ten… Urban Legends of Forensic Science

7. Courtroom decisions validate science (i.e., my method is correct because the jury found the defendant guilty)

6. I can only rely on people that agree with me and who work in my specific discipline (i.e., no one else can understand my problems)

5. It is not my fault if the people in the courtroom don't understand my testimony

Top Ten… Urban Legends of Forensic Science

4. Defense lawyers are evil and should not have access to my data

3. I have never made a mistake – therefore MY error rate is zero!

2. DNA is problem-free – so says the NRC! (NAS 2009 report, p. 7)

Top Ten… Urban Legends of Forensic Science

1. Let's give this problem to the statisticians – **they will all agree** on an appropriate solution!

Additional Urban Legends

- Proficiency tests are a measure of my ability to do casework accurately
- Scientific methods do not and should not evolve or improve
- My research will solve their problem (without ever trying to understand the real problems involved)
- If a case ends up on my desk, it is likely that the person involved in the case is guilty of something
- Everything should follow cookbook-like recipes
- Definitions for words we use mean the same for everyone
- Solving this problem to the fourth decimal place is necessary to demonstrate that this method is fit-for-purpose
- If no one challenges my testimony in court, then what is wrong with what I am doing?
- We don't have time to do improve the science – we have ongoing cases

American Academy of Forensic Sciences

Jurisprudence Section

Orlando, FL

February 20, 2015

ORLANDO 2015

http://www.cstl.nist.gov/strbase/pub_pres/Butler-DNA-interpretation-AAFS2015.pdf

Why DNA Interpretation Has Become More Challenging in Recent Years

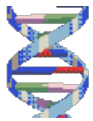
John M. Butler, Ph.D.

NIST Fellow & Special Assistant to the Director for Forensic Science

National Institute of Standards and Technology

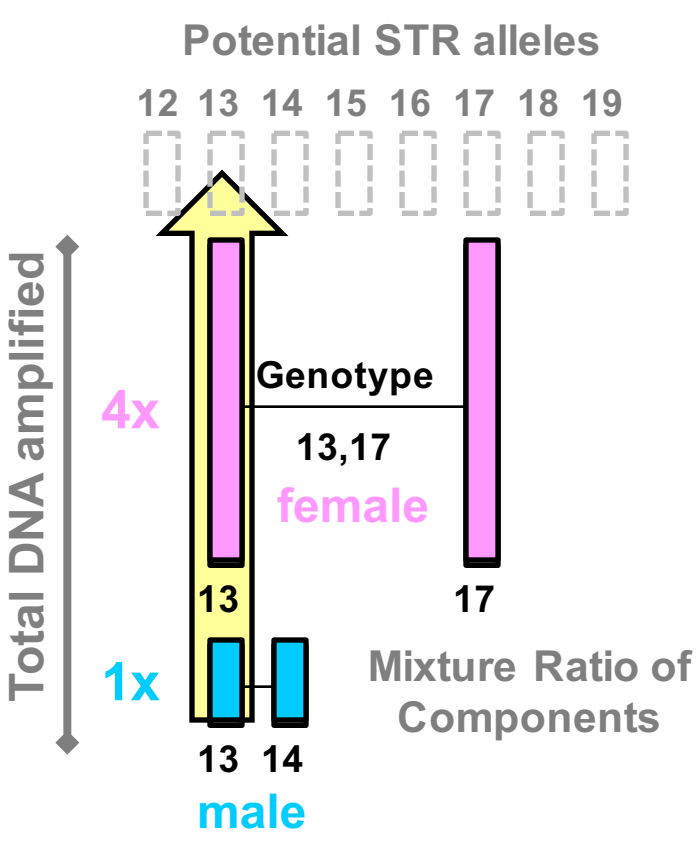
Gaithersburg, Maryland

NIST FORENSIC SCIENCES



NIST

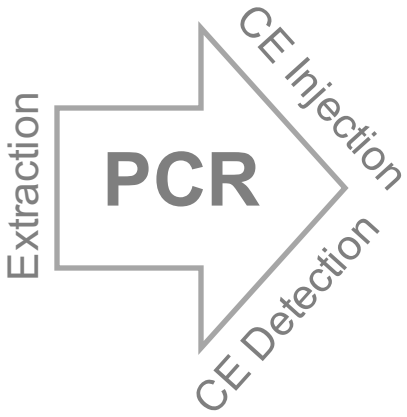
True Sample Components → Sample Processing → DNA Data Obtained



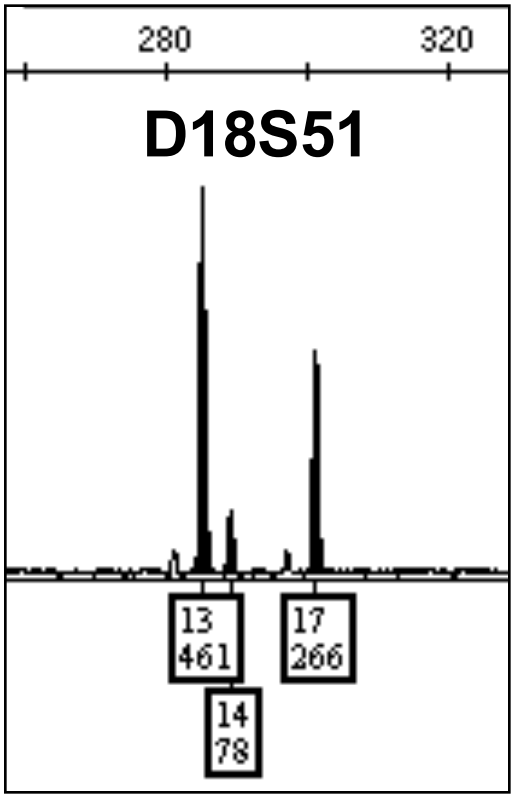
Potential Allele Overlap & Stacking

Number of Contributors
(sample components)

Validation
establishes variation and limits in the processes involved



portion of a CE electropherogram



Infer possible genotypes & determine sample components

From available data

Goal of Interpretation

5 Reasons that DNA Results Are Becoming More Challenging to Interpret

1. **More sensitive DNA test results**
2. **More touch evidence samples** that are poor-quality, low-template, complex mixtures
3. **More options exist** for statistical approaches involving probabilistic genotyping software
4. **Many laboratories are not prepared** to cope with complex mixtures
5. **More loci being added** because of the large number of samples in DNA databases

http://www.cstl.nist.gov/strbase/pub_pres/Butler-DNA-interpretation-AAFS2015.pdf

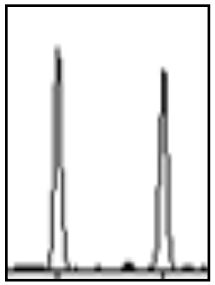
Math Analogy to DNA Evidence

$2 + 2 = 4$

$2x^2 + x = 10$

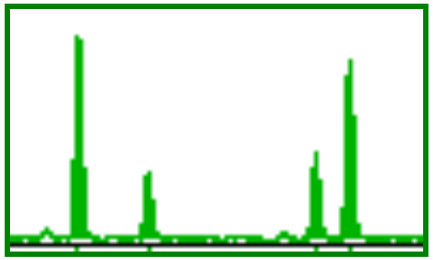
$$\int_{x=0}^{\infty} f(x)\,dx$$

Basic Arithmetic



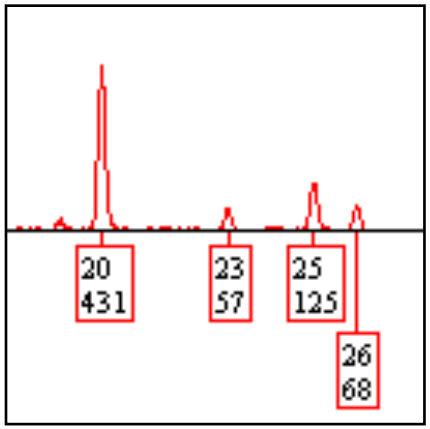
Single-Source DNA Profile
(DNA databasing)

Algebra



Sexual Assault Evidence
(2-person mixture with high-levels of DNA)

Calculus



Touch Evidence
(>2-person, low-level, complex mixtures perhaps involving relatives)

http://www.cstl.nist.gov/strbase/pub_pres/Butler-DNA-interpretation-AAFS2015.pdf

Many laboratories are not prepared
to cope with complex mixtures

- Have **appropriate validation studies** been performed to inform proper interpretation protocols? (curriculum & classroom instruction)

- Are **appropriately challenging proficiency tests** being given? (graded homework assignments)

- **Would we want to go into a calculus exam only having studied algebra and having completed homework assignments involving basic arithmetic?**

Historical Perspective on DNA Mixture Approaches

Probabilistic genotyping software in development…

LR commonly used in Europe and other labs around the world

ISFG DNA Commission
LR with drop-out
2012

Today

2013 DNA TL Summit

SWGDAM guidelines
(RMP, CPI, LR)

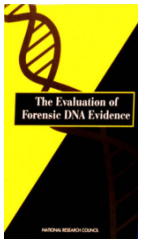
ISFG DNA Commission
LR over CPI
2006

2010

complex mixtures increase

2-person mixtures predominate

Few mixtures



Weir et al. describe LRs for mixtures

1997

NRC II report (p.130) supports LR

1996

Evett et al. describe LRs for mixtures

1991

2008 NIJ burglary report increases touch evidence

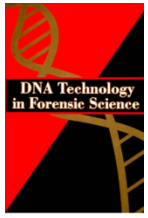
2000

DAB Stats
(Feb 2000)
CPI and LR okay

CPI becomes routine in U.S.

1992

NRC I report (p.59) supports CPI



1985

RMNE (CPI) used in paternity testing

LR = likelihood ratio
CPI = combined probability of inclusion
RMNE = random man not excluded

Why are we where we are today?

- The incredible success of DNA has lead to more sensitive methods and more samples being provided which has led to more complex mixtures (we are pushing the envelope)
  - Lower template DNA profiles have more uncertainty associated with them in terms of allele peak height variation

- Statistical interpretation techniques have not kept pace with the methodology improvements
  - Much of the forensic DNA community is effectively using a 1992 statistical tool (CPI) on 21st century data

Thoughts on Potential Improvements

Know the literature

Know the question being asked

Know the limits of what you can do

Know the Literature…

- We must do our homework – and read the literature!
- A brief bibliography is included with this workshop:
  - http://www.nist.gov/itl/iad/ig/forensic_biblio.cfm
- **AAFS 2016 workshop**
  - **Information Does Exist Beyond the First Page of Your Google® Search!:** Tools and Strategies for Forensic Science Literature Searching and Use
  - Search tools and strategies are described
  - Slides available at http://www.cstl.nist.gov/strbase/training/AAFS2016_LiteratureWorkshop.htm

Steps in Forensic DNA Analysis

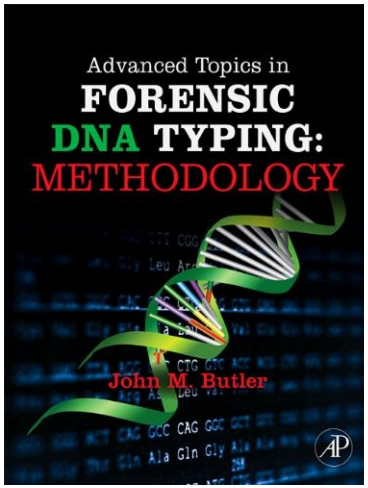
Understanding Results Obtained & Sharing Them

Gathering the Data

Interpretation

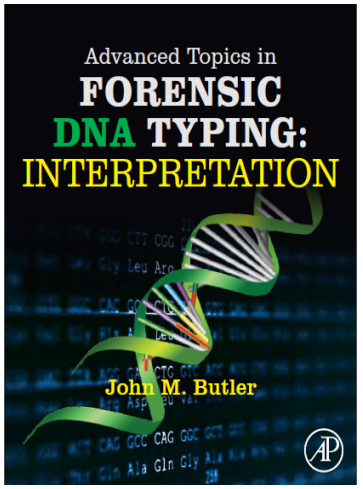
>1300 pages of information with >5000 references cited in these two books

Advanced Topics: Methodology



August 2011

Advanced Topics: Interpretation



October 2014

Know What Question You Are Trying to Answer

David Balding
University of Melbourne
Professor of Mathematics and Statistics

"…**Focus on the relevant question**. Many misleading statistical approaches [turn] out to be providing valid answers to the wrong questions."

– David Balding, Interpreting DNA evidence: can probability theory help? In J.L. Gastwirth (ed.) *Statistical Science in the Courtroom* (pp. 51-70) New York: Springer, 2000

Different Calculations Answer Different Questions

Method used	Questions being answered
Profile probability (random match probability, RMP)	What is the rarity of a specific DNA profile given the alleles observed? **What is the chance that a particular profile exists** in a population based on allele frequencies?
Match probability	Given that a particular profile has been seen (in the crime scene evidence and in the suspect), **what is the chance of it occurring again?**
Database match probability	How often would a DNA profile match the relevant forensic sample in a database of size *N*?

Adapted from Table 11.7, J.M. Butler (2015) *Advanced Topics in Forensic DNA: Interpretation* (Elsevier Academic Press)

Ian Evett on Interpretation

"The crucial element that the scientist brings to any case is the *interpretation* of those observations. This is the heart of forensic science: it is where the scientist adds value to the process."

Evett, I.W., et al. (2000). The impact of the principles of evidence interpretation on the structure and content of statements. *Science & Justice, 40,* 233-239.

Consider Carefully the Question Being Addressed with Your "Solution"

John Tukey
American statistician
(1915-2000)

- "Far better an approximate answer to the right question, which is often vague, than the exact answer to the wrong question, which can always be made precise." (Brillinger, *Ann. Stats.* 2002, 30, 1535-1575)

- An approximate answer to the right problem is worth a good deal more than an exact answer to an approximate problem. (http://quotesgram.com/john-tukey-quotes/)

Know the Limits of What You Can Do

- I have advocated for development of a "complexity (or uncertainty) threshold" with DNA evidence interpretation

New Scientist article (August 2010)

- **How DNA evidence creates victims of chance**
  - 18 August 2010 by Linda Geddes
- From the last paragraph:
  - **In really complex cases, analysts need to be able to draw a line** and say "This is just too complex, I can't make the call on it," says Butler. "Part of the challenge now, is that every lab has that line set at a different place. But the honest thing to do as a scientist is to say: **I'm not going to try to get something that won't be reliable**."

http://www.newscientist.com/article/mg20727743.300-how-dna-evidence-creates-victims-of-chance.html

Information from Chapter 7 of my New Book

Advanced Topics in Forensic DNA Typing: Interpretation

CHAPTER

7

Low-Level DNA and Complex Mixtures

"The limits of each DNA typing procedure should be understood, especially when the DNA sample is small, is a mixture of DNA from multiple sources, or is contaminated with interfering substances."

NRC I, 1992, p. 8

"For the complex DNA profile, there is no predominant or overarching standard interpretation method."

Peter Gill (Gill et al. 2012, report to the UK Forensic Science Regulator, p. 18)

"The limits of each DNA typing procedure should be understood, especially when the DNA sample is small, is a mixture of DNA from multiple sources…" (NRC I, 1992, p. 8)

Butler, J.M. (2015) *Advanced Topics in Forensic DNA Typing: Interpretation* (Elsevier Academic Press: San Diego), pp. 159-182

Perhaps We Should Slow Down with Some of the DNA Mixtures That We (Scientists and Lawyers) Are Taking On…

Poor Quality Conditions

Large Numbers of Contributors

Lessons from History

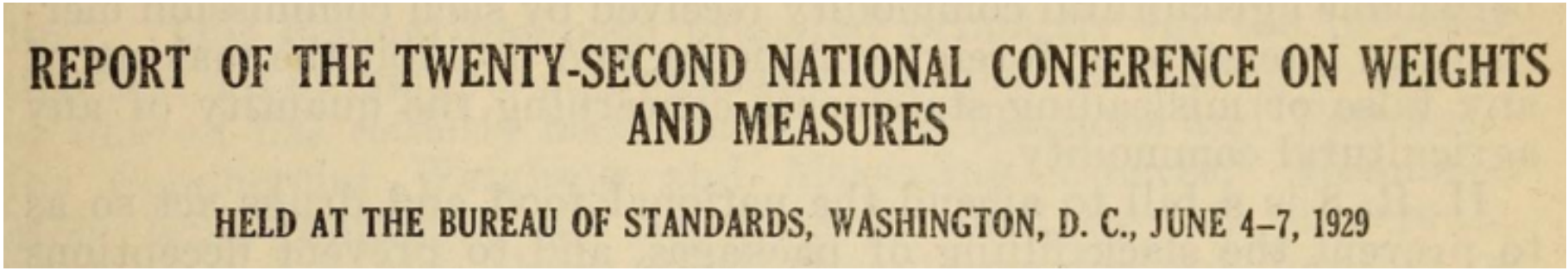
Why does this matter?

“Those who don't know history are doomed to repeat it.”

— Edmund Burke (Irish statesman in 1700s who supported American colonies’ independence)

http://www.goodreads.com/quotes/111024-those-who-don-t-know-history-are-doomed-to-repeat-it

A June 5, 1929 Presentation by **Wilmer Souder** at the National Conference on Weights and Measures (NCWM) Launched the NBS Identification Laboratory


REPORT OF THE TWENTY-SECOND NATIONAL CONFERENCE ON WEIGHTS AND MEASURES

HELD AT THE BUREAU OF STANDARDS, WASHINGTON, D. C., JUNE 4–7, 1929

IDENTIFICATION BY PRECISION METHODS OF COMPARISON AND MEASUREMENT

By WILMER SOUDER, *Bureau of Standards*

Introduction

Identifications by comparisons have been made with more or less success for centuries. The application of precision-measurement methods for these purposes is of recent origin and is not generally understood. This lack of understanding of the principles upon which the science is based is responsible for the confusion so often resulting from evidence introduced in courts of law.

Usual Methods

We are so accustomed to the usual methods of description, which are only approximate and by virtue of these approximations are susceptible of no precise interpretations, that we fail to recognize the extreme accuracy of indentifications made by precision measurements.

When we say we are looking for a man 6 feet tall of rather heavy build, with dark hair, with a scar on one hand and with some gold teeth in his mouth we should not be surprised to find several hundred citizens of the United States who meet the description. If we increase the precision of the description to a man 72½ inches tall, weighing 207 pounds, index finger of left hand amputated at the second joint, and with gold crowns on left cuspid and right bicuspids, we may feel sure there is not more than one man in the entire country who will meet the specifications, and having found this one, further search can not be justified without the introduction of some unusual condition.

Justification from Probability

The justification for this definite conclusion of positive identification is based on the "law of probability." Briefly, and in nontechnical terms, this law is interpreted from the fraction which represents the ratio of the number of times a specific characteristic appears divided by the maximum number of appearances possible,

74737—29——5

- Souder is given a prime speaking slot immediately following the Secretary of Commerce (Robert P. Lamont)
- He discusses the value of precision measurements for typewriting, handwriting, and ballistics, and **introduces probabilistic interpretation** (essentially a likelihood ratio approach)
- Newspaper reports are published of his remarks

THE DAILY NORTHWESTERN, WEDNESDAY EVENING, JUNE 5, 1929

Oshkosh, Wisconsin newspaper article

ERLOCK HOLMES OF TOMORROW WILL BE STANDARDIZED

Attempts to Destroy Beacon Lights of Evidence Seldom Successful, Claim

(By Oscar Leiding, Associated Press Science Editor)

Washington —(AP)— The Sherlock Holmes of tomorrow will not be a detective solving baffling mysteries by his own cleverness but a scientific expert relying upon standardization methods of precise identification.

This prediction was made by Wilmer Souder of the bureau of standards, in placing before the national conference of weights and measures the bureau's work with the problems of identification.

The cunning criminal, who masks his face and gloves his hands, the expert showed, will find himself pitted against the cold scrutiny of supermicroscopes that will tear his identity from a type-written document, a pistol ball, a cartridge shell, or a signature.

LOGICAL, PRECISE

Experts who make identifications in a logical, precise manner will replace "the socalled experts who recognize no limitations, and no equipment as essential in their field," Mr. Souder said.

In an effort to establish standards for this class of work, it was explained, the bureau has taken up the problems of identification of written and typewritten documents, signatures, guns, and bullets.

The slightest defects and variations that distinguish one typewriter from another are susceptible, it has found, to precision measurements which, when analyzed by an expert, are sufficient to establish the identity of a machine.

MUST BE PERFECT

Attempts to destroy "these beacon lights of evidence," Mr. Souder said, "are seldom successful and would require, on the part of the one who seeks to mask them, a perfect analysis of every defect with equipment not readily available."

Ballistic identifications, which have as their purpose the determination of the gun from which a certain bullet was fired, may be made by measurements and comparisons.

Marks left on a ball by the grooves of a pistol barrel, the imprint of a firing pin and breech markings on a shell, rust spots and injuries to the inner surface of a barrel, he said, are all measurable traces.

Wisdom of Wilmer Souder

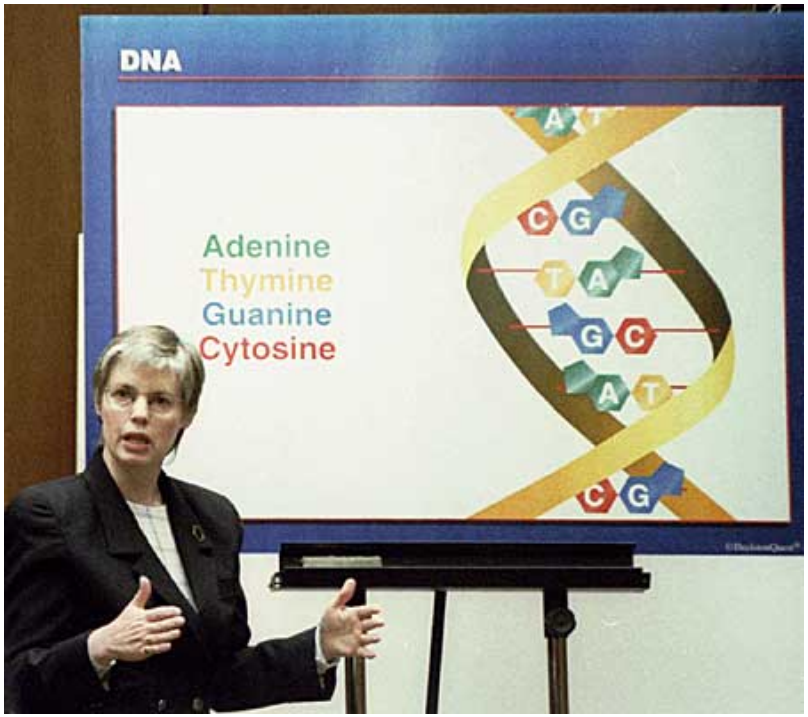
National Bureau of Standards (1911-1913, 1917-1954)

"The honest expert never looks upon the outcome of his work as a result of luck, the reward of a game, or victory in a battle of wits. He has built his qualifications through hard work. He establishes his conclusions through exacting procedures; he presents his testimony in the face of keen opposition and asks no favor beyond an honest consideration of the facts disclosed. Having done so, he has fulfilled the high obligations of his profession.

"**Justice is sometimes pictured as blindfolded. However, scientific evidence usually pierces the mask**."

- **Wilmer Souder**, "Effective Testimony for Scientific Witnesses", *Science* (1954) 119: 819-822

Forensic Scientists Should Represent the Data – Not a Particular Side in the Courtroom Drama



Dr. Robin Cotton testifying in the O.J. Simpson case (May 1995)

Dr. Robin Cotton speaking about the role of forensic scientists in court:

"You are the voice of the data!

You are not a voice for the victim, which is what some prosecutor's describe their role as. …You just cannot behave like you are on their side. You cannot let that feeling influence how you behave, how you speak, and most importantly, how you look at the data. … It is the prosecutor who is supposed to worry about the consequences of the trial. **If you represent the data accurately in a scientific sense, then it is hard to go wrong.**"

From Chapter 18 in J.M. Butler (2012) *Advanced Topics in Forensic DNA Typing: Methodology* (Elsevier Academic Press: San Diego)

National Commission on Forensic Science (NCFS):
www.justice.gov/ncfs

Organization of Scientific Area Committees (OSAC):
www.nist.gov/forensics/osac/index.cfm

NIST FORENSIC SCIENCES

www.nist.gov/forensics

301-975-4049 john.butler@nist.gov

NIST FORENSIC SCIENCES

Biannual Conference to Showcase NIST Research

Previous Meetings:

November 28-30, 2012 at NIST

December 3-4, 2014 at NIST

Next Meeting:

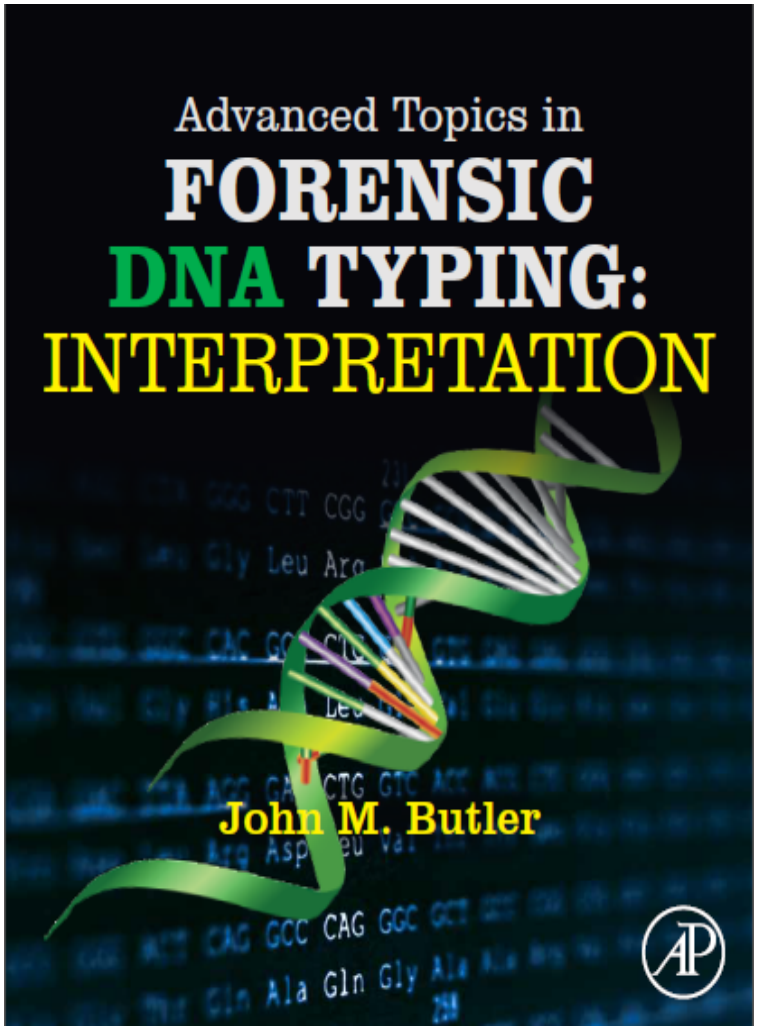
November 8-9, 2016

Gaithersburg, MD

http://www.nist.gov/oles/forensics-2012.cfm

http://www.nist.gov/forensics/forensics-at-nist-2014.cfm

Some Interesting Features to this Audience



Elsevier Academic Press (2015)

- Better Know a Statistician