Law and Science

"Law is a normative pursuit that seeks to define how public and private relations *should* function…In contrast…science is a descriptive pursuit which does not define how the universe should be but rather describes how it actually *is*.

Moreover, in almost every instance, scientific evidence tests the abilities of judges, lawyers, and jurors, all of whom may lack the scientific expertise to comprehend the evidence and evaluate it in an informed manner."

Developments in the law – confronting the new challenges of scientific evidence. 108 HARV. L. REV. 1482, 1484 (1995).

The Principles of Science and Interpreting Scientific Data

"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 (1687, 1713, 1726) "Rules for the study of natural philosophy," *Philosophiae Naturalis Principia Mathematica*
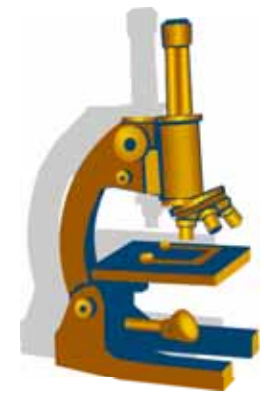
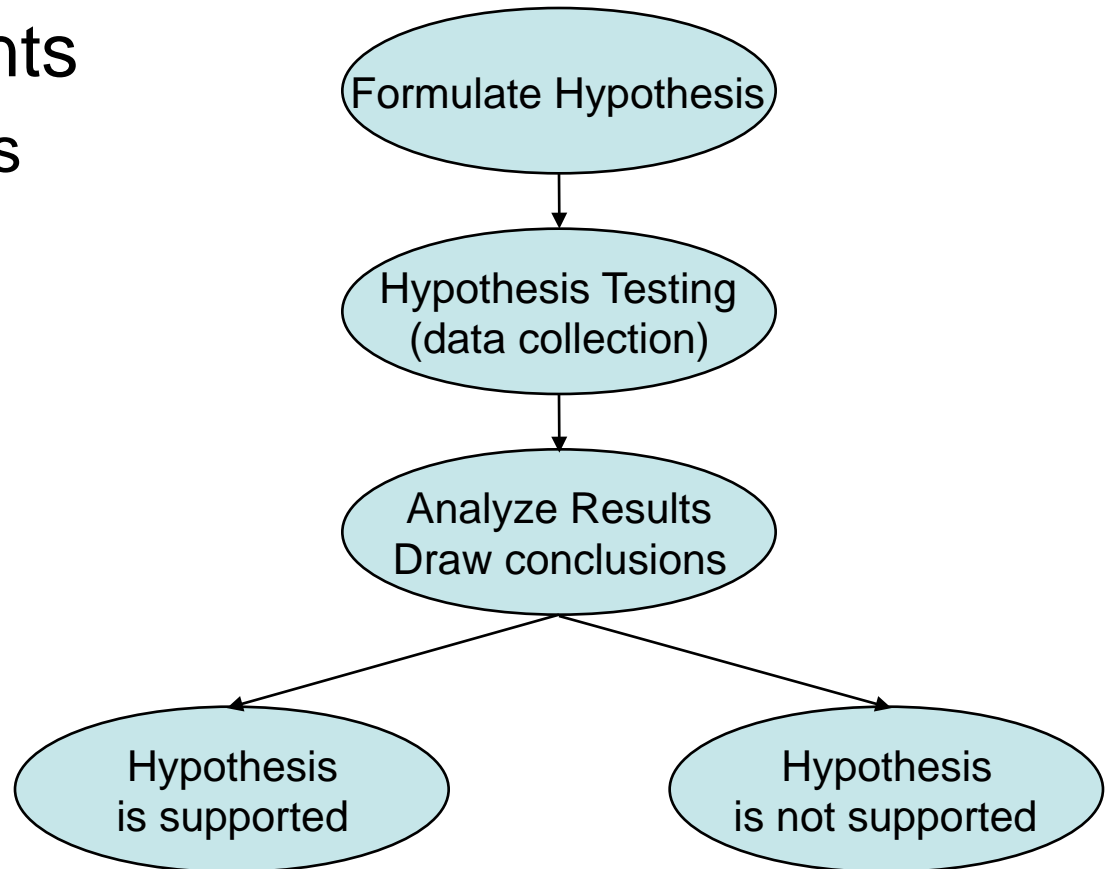# Improving Methods, Practice, and Performance in Forensic Science

Reporting Results

"There is a critical need in most fields of forensic science to raise the standards for reporting and testifying about the results of investigations."

Reporting Results

Minimum Requirements

- Methods and materials
- Procedures
- Results
- Conclusions
- Identify uncertainty (Confidence level)

Formulate Hypothesis

Hypothesis Testing (data collection)

Analyze Results Draw conclusions

Hypothesis is supported

Hypothesis is not supported

FBI Response

- Formation of the Interpretation and Report Writing Working Group (IRWWG)
  - Representatives from case working units
    - Chemistry
    - DNA (Nuclear and Mito)
    - Explosives
    - Firearms/Toolmarks
    - Latent Prints
    - Questioned Documents
    - Trace Evidence
  - Quality Assurance and Training Unit
  - Management
- To revise current FBI reporting procedures to comply with minimum requirements of NAS report

Methods and Materials/Procedures

- SWGMAT Expert Reporting Guideline section 4.2.2. The report shall contain…
  - General examinations conducted, including generic class and type of instrumentation used for examinations or determinations
- FBI TEU SOPs Report Writing Section
  - When a glass/hair/etc analysis is performed, the report will include an identification of the examination(s) being performed, a listing of the technique(s) used for analysis, interpretation, limitations associated to the analyses performed, results of the analysis, conclusions, and the comparison criteria used for any specimens being compared. Reports containing glass results will comply with the Scientific Working Group for Materials Analysis (SWGMAT) Expert Reporting Guideline.

Methods and Materials/Procedures Example - Hair

A microscopic hair comparison was performed between specimens Q1 through Q3 and specimens K1 and K2. The results of the trace
evidence (hair) examinations are included in this report.

Methods:

Microscopic comparison of hairs for the purposes of determining the possibility of a common origin is accomplished by using one or more analytical techniques. These techniques include in determination of gross physical characteristics using a stereobinocular microscope, and the examination of microscopic characteristics using a comparison microscope.

Methods and Materials/Procedures Example - Glass

Methods:

Comparison of glass items for the purposes of determining the possibility of a common origin is accomplished by using one or more analytical techniques. These techniques include:

•Examinations of fracture surfaces for fractography are conducted using stereobinocular   and/or compound microscopes.

•Determination of physical properties such as glass type, glass color, and thickness. The   physical properties of the glass are determined using stereobinocular and petrographic microscopes, micrometers, and ultraviolet lights.

•Measurement of the refractive index at up to three wavelengths, 488nm, 589nm, and 656nm. Refractive index of the glass is measured using the Foster + Freeman, Ltd. Glass   Refractive Index Measuring system (GRIM3).

•Determination of the concentrations of aluminum, barium, calcium, iron, magnesium, manganese, sodium, strontium, titanium, and zirconium. The elemental concentrations are   determined using a Perkin-Elmer Optima 3300 inductively coupled plasma - optical   emission spectrometer (ICP-OES).

The actual tests performed are dependent on the size and shape of the glass fragment, and analytical requirements. In this case, a fractography examination was conducted between glass specimen Q1 and the known glass specimen K1.

Additionally, a comparative glass examination was conducted between glass specimens Q2 through Q4 and the known glass specimen K1. The physical properties expressed in the glass were determined using stereobinocular and petrographic microscopes. Multiple measurements of refractive index at 589nm wavelength and of the concentrations of the ten above listed elements were acquired.

Results/Conclusions

- SWGMAT Expert Reporting Guideline section 4.2.3. The report shall contain…
  - Results of examination (e.g., the two compared samples are indistinguishable in measured properties).

- SWGMAT Expert Reporting Guideline section 4.3
  - Opinions and Conclusions
    - It is the responsibility of the examiner to use only significant data in the evaluation of evidence. The opinion(s) should be based only on such data. Conclusions should be consistent with all of the significant data developed and accepted scientific principles.

Results/Conclusions
Example - Glass

Conclusions:

Specimen Q1 physically fits together with a piece of glass from specimen K1. Consequently, the piece of glass recovered specimen Q1 was once part of the K1 source of glass.

Specimens Q2 through Q3 are physically indistinguishable from specimen K1. The measured ranges plus the measurement uncertainty of the refractive index and elemental concentration values of glass specimens Q2 and Q3 overlap with those of the specimen K1 glass. Consequently, glass specimens Q2 though Q3 either originated from the K1 source of glass, or from another source of broken glass coincidentally indistinguishable in all of the measured or observed physical properties, refractive index, and elemental composition.

Specimen Q4 is compositionally different from specimen K1. Consequently, glass specimen Q4 did not originate from known source of glass as represented by specimen K1.

Limitations - Hair

- The comparison of the microscopic characteristics in hairs does not constitute a basis for absolute personal identification.
- Hair color and texture may change as a person ages. Hair comparisons may be inappropriate where a considerable length of time exists between the deposition of questioned hairs and the collection of known hair samples.
- Hair is readily altered by cutting or through the application of chemical agents that may change the texture or color of the hair. Hair that has been altered between the time of the possible transfer and collection of a known sample may be inappropriate for comparison purposes.
- Some hairs (e.g. short hairs) may express a limited number of features for comparison.
- The amount of variability in human hairs not from the head or pubic area has not been well studied, and the variation between individuals is not known. While it is possible to exclude a person as a potential donor of these types of hairs when the hairs compared are different, it is not typically appropriate to associate these hairs.
- Animal hairs do not always possess sufficient microscopic characteristics to distinguish between members of the same breed.

Limitations - Glass

A forensic glass analysis is typically a comparison of two or more glass fragments in an attempt to determine <u>if they originated from different sources</u>. These analyses require the determination of class characteristics that may associate objects with a group of similar objects such as containers, but never to a single object. It is important to note, however, that although there may be several objects with identical properties, glass fragments can originate only from broken and not intact objects. Only when two or more broken glass fragments physically fit together can it be said that they were once part of the same object.

Additional limitations are in each instrument specific SOP (e.g. ICP-OES is a destructive technique).

Changing the Null Hypothesis

Formulate Hypothesis

- Current hypothesis:
  - Is there an association between the questioned hair, fiber, glass, etc. and the known source?
- Suggested change:
  - Is the questioned hair, fiber, glass, paint, etc. from a different source than the known source?

Hypothesis Testing
(data collection)

Changing the Null Hypothesis

Analyze Results Draw conclusions

Hypothesis is supported

Hypothesis is not supported

- "If a significant difference is found between samples being compared, this analysis may be discontinued." FBI TEU Glass SOP
- Then→ The hypothesis is supported. The Q and K came from different sources.
- Else → The hypothesis is not supported. The K cannot be eliminated as a source of the Q.
  - The "cannot be eliminated" is based on the tests performed.

Interpretation Example - Glass

The physical properties expressed in the glass and the resultant range of refractive index values plus the measurement uncertainty and the concentrations of aluminum, barium, calcium, iron, magnesium, manganese, sodium, strontium, titanium, and zirconium plus the measurement uncertainty are used as the comparison criteria when specimens do not physically fit together. When the physical properties assessed are indistinguishable and the ranges of the refractive index and elemental concentration values overlap, the possibility that the compared fragments originated from the same source of broken glass cannot be eliminated.

The variations in the observed and measured properties within a glass object are typically smaller than the variations among objects. The probability of a random occurrence of glass with indistinguishable elemental composition and refractive index at 589nm is estimated to be between 10-5 and 10-13. In other words, the chance of finding glass with coincidentally indistinguishable refractive index and elemental composition alone is 1 in 100,000 to 1 in 10 trillion, which <u>strongly supports</u> the supposition that a recovered glass fragment and a broken object with indistinguishable refractive index at 589 nm and elemental composition are unlikely to be from another source. Although these are not direct indicators of the rarity in any specific case, they can be used to show that the probability of a coincidental match is rare.

- Koons, R. D. and Buscaglia, J. The forensic significance of glass composition and refractive index measurements, Journal of Forensic Sciences (1999) 44:496û503.

Interpretation
Example - Glass

In glass specimens where only refractive index data can be measured, the chance of finding glass with coincidentally indistinguishable refractive indices is significantly higher. Analysis of a database of glass refractive indices from glass collected in forensic casework indicates that at the most common refractive index, approximately 9% of all glasses may have a coincidentally indistinguishable refractive index at 589 nm. This number will be lower for other, less common refractive indices and when more wavelengths are measured. It should be noted that the database used to calculate this number is based on samples that have been submitted to the FBI Laboratory as a part of forensic casework, and may not be representative in a specific case.

For additional information on forensic glass analysis and results interpretation, please see Bottrell, Maureen, "Forensic Glass Comparison: Background Information Used in Data Interpretation," Forensic Science Communications, April 2009, http://www.fbi.gov/hq/lab/fsc/current/review/ 2009_04_review01.htm.

Interpretation Example - Hair

The physical characteristics of hairs differ between individuals, between body areas, and across a single body area on a particular individual. The differences between individuals and body areas are distinct, and are typically greater than the variation in characteristics observed in a single body area of a particular individual.

The range of physical characteristics expressed in the hairs was used as the comparison criteria. When the appearance, arrangement, and distribution of microscopic characteristics expressed between a recovered hair and a potential source are indistinguishable, the possibility that the compared hairs originated from the same source cannot be eliminated. Consequently, the recovered hairs are consistent with originating from the known source, although the association of hairs using physical characteristics does not constitute a basis for absolute personal identification.

Interpretation Example - Hair

The inability to associate specimens through a microscopic hair examination does not preclude that the persons of interest/items of interest had contact with each other. A number of factors can produce this result, including: 1) Hair evidence may not have transferred. 2) Hair that did transfer may have been lost prior to submission to the laboratory. 3) The hair transferred or the comparison specimen submitted may not be representative of the source. 4) The hair may be from a different source.

For additional information on microscopic hair comparison and results interpretation, please see Oien, Cary, "Forensic Hair Comparison: Background Information for Interpretation," Forensic Science Communications, April 2009, http://www.fbi.gov/hq/lab/fsc/current/review/2009_04_review02.htm.

Additional Information

- SWGMAT Expert Reporting Guideline section 4.5
  - Certain additional information must be maintained by the laboratory. This information shall be recorded in the report, attached as an appendix, or documented in the case records or laboratory files. A statement will be included in the report to indicate the location of the additional information.

- Example from a glass report
  - The supporting documentation for the opinions and interpretations expressed in this report is retained in the FBI Laboratory files. For questions about the content of this report, please contact Geologist/ Forensic Examiner Jane Doe at (703) 632-9876. For questions regarding the status of the specimens, please contact Evidence Control Unit Request Coordinator John Smith at (703) 632-0123.