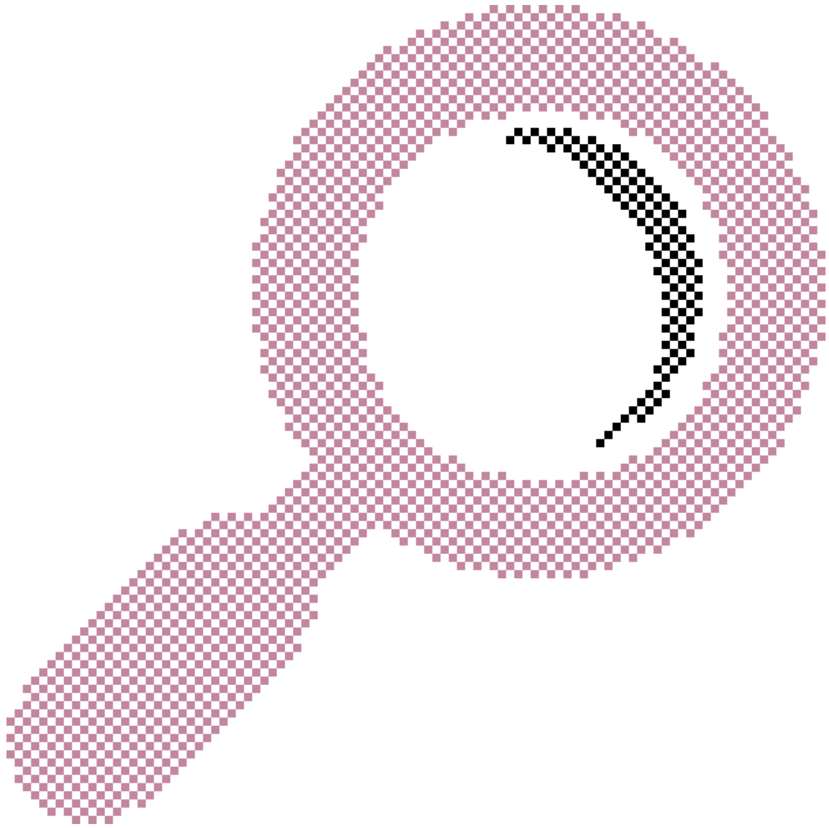


A Simplified Guide To Trace Evidence

Introduction

At a crime scene, there are often tiny fragments of physical evidence such as hairs, fibers from clothing or carpeting, or pieces of glass that can help tell the story of what happened. These are referred to as trace evidence, and can be transferred when two objects touch or when small particles are disbursed by an action or movement. For example, paint can be transferred from one car to another in a collision or a hair can be left on a sweater in a physical assault. This evidence can be used to reconstruct an event or indicate that a person or thing was present.

Careful collection of materials from a crime scene can yield a wealth of information about where a sample came from and how it helps to tell the story. Scientists examine the physical, optical and chemical properties of trace evidence and use a variety of tools to find and compare samples, and look for the sources or common origins of each item. Most test methods require magnification and/or chemical analysis.

Fibers are carefully collected from a jacket for examination. (Courtesy of NFSTC)

The importance of trace evidence in the context of crime scene investigation is sometimes understated, taking a back seat to more individualized evidence such as DNA or fingerprints. Much can be learned about what happened at a scene through trace evidence, such as whether an item or body was moved or whether someone was assaulted from behind or the side. Trace evidence can include a wide variety of materials, but the most commonly tested are hair, fibers, paint and glass. Other, less frequently included items are soil, cosmetics and fire debris. Some laboratories will consider fire accelerants as trace and others will include them in chemistry, even though the same tests are conducted in both laboratories. For the purposes of this series, paint, glass, fiber, and hair will be included in the discussion.

Principles of Trace Evidence

In the early 20th century, Dr. Edmond Locard, a forensic science pioneer in France, formulated the theory which states, “Every contact leaves a trace”. This became known as Locard’s exchange principle and is the basis for all forensic science as we know it today.

Linking People, Places and Things

Trace evidence can be used to link people or objects to places, other people or other objects, and often serves as a starting point, or lead, for a particular line of investigation. Trace evidence helps to put together pieces of the investigative puzzle—from which direction did the perpetrator arrive? How close was the victim to the window when the bullet shattered the glass? Were stolen goods transported in a particular vehicle? The answers to these questions can significantly impact the outcome of a trial and these answers may be found via careful examination of tiny bits of evidence.

Important developments in trace evidence came alongside advances in microscopy, chemical analysis, and for evidence comparison purposes, database technology.

As the capabilities, availability and networking of comparison databases from scientists and manufacturers became more robust, samples of items such as paint, glass and even soil could be compared against known standards to provide solid and consistent classifications. For example, the National Automotive Paint File is a Federal Bureau of Investigation (FBI) database containing more than 45,000 samples of automotive paint from manufacturers dating back to the 1930s[1]. Sherwin-Williams® Automotive Finishes also maintains a large database, Formula Express® (http://sw.formulaexpress.com/), which can be very helpful in identifying year, make and model based on color availability. The National Institute of Justice maintains a list of some available databases (http://www.nij.gov/journals/258/forensic-databases.html).

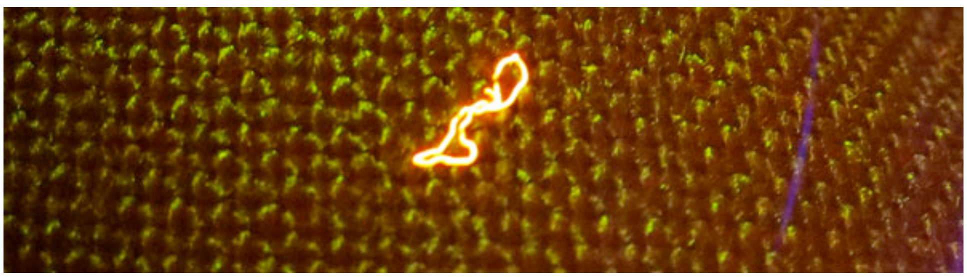
Trace investigators must stay abreast of advances in manufacturing techniques, materials, coatings and processes. Every item that can be

[1] FBI Laboratory Services, Chemistry (http://www.fbi.gov/about-us/lab/scientific-analysis/chem)

touched or transported has the potential to become trace evidence, therefore, investigators and analysts must consider the potential that a product may have a new or updated version available.

Why and when is trace evidence used?

Every case potentially has trace evidence to consider, and investigators must use their knowledge, training and experience to thoroughly examine the scene, identifying and properly collecting the most probative evidence, including traces. This examination includes a focused search for and careful collection of anything that may yield clues or the potential for identifying key players.



Tiny fibers can be seen and collected using a variety of techniques such as alternate light sources. In this image, a tiny fiber fluoresces and is easily gathered from an article of clothing. (Courtesy of NFSTC)

An examination for trace evidence could happen at a crime scene, on victim's or suspect's clothing, or a location the victim or suspect may have been recently. For example, trace examiners may look for ligature fibers in the case of a strangling to identify what might have been used to commit the crime, or gunshot residue around a bullet hole to indicate the distance between a shooter and a victim. The body, clothing and jewelry of a crime victim are investigated for trace materials using the same precision methods as would be used at a crime scene.

In the investigation of a crime scene, investigators must prioritize what items will be collected and sent to the lab, and in what order it should be processed. Investigators using a holistic approach to the scene will gather evidence and prioritize each item by assessing its value based on the level of identification it may provide.

Trace examiners use tools such as tweezers, tape, specialized vacuums, swabs, alternate light sources, and lasers to find and collect trace evidence.

Following the principles of proper crime scene investigation, the collected materials are packaged, documented and sent to a crime laboratory for analysis.

Trace evidence collection tools. (Courtesy of NFSTC)

One of the most famous cases involving trace evidence was that of Wayne Williams, convicted of two counts of murder in 1982 in the infamous Atlanta Child Murders case. For a period of 22 months beginning in 1979, 30 black children and young men had disappeared or died under suspicious circumstances. Through the investigation, trace examiners found fibers and animal hairs that could not be excluded when looking for links between the cases. By identifying the fibers as carpeting, finding the manufacturer and computing probability statistics regarding the chance that they could have come from somewhere other than William's home, investigators were able to begin to use this evidence to tie the victims to Williams. In doing the same with the animal hair in comparison with Williams' dog, then calculating the statistics that someone would have a dog and carpeting that would be consistent with those of Williams made the case very strong and resulted in a conviction. In this example, trace evidence was the centerpiece of the prosecutor's case and only careful evidence collection and examination made it possible.

How It's Done

Evidence That May be Collected

Hair - Analysts can tell investigators if individual hairs are human or animal, and in the case of human hair, where on the body the sample originated. Samples can be tested to determine the color, shape and chemical composition of the hair, and often the race of the source individual. The presence of toxins, dyes and hair treatments are noted. This information can assist investigators in including or excluding particular individuals as the source of the hair. If the hair still has a follicle (root) attached, DNA testing may be used to identify an individual; otherwise, hair comparison is typically used only to exclude.

Collection: Collected samples are sent to the laboratory along with control samples from a suspected individual. Control samples should include hair from all parts of the head and, for pubic hair, the area should be combed for foreign hairs prior to sample collection. Hair samples are primarily collected using tweezers.

Fiber - Fibers are threadlike elements from fabric or other materials such as carpet. Most are easily identifiable under a microscope. Fibers fall into three classifications: natural (animal or plant fibers like wool, cotton or silk), synthetic (completely manmade products including polyester and nylon) and manufactured (containing natural materials that are reorganized to create fibers such as rayon).

Fibers are useful in crime scene investigation because their origins can be identified. A carpet fiber on a person's shoe can indicate the individual's presence at a crime scene. However, fibers are very mobile and can become airborne, get brushed off or fall from clothing. This mobility makes timely collection crucial to prevent loss of material or cross-contamination.

Collection: Fibers cling to other fibers and hair, but may be easily brushed off. When approaching a scene, investigators will attempt to pinpoint the most probable locations for deposited fibers. For example, the carpeting under and surrounding a victim's body, clothing from the victim or a suspected weapon are likely places to find fibers.

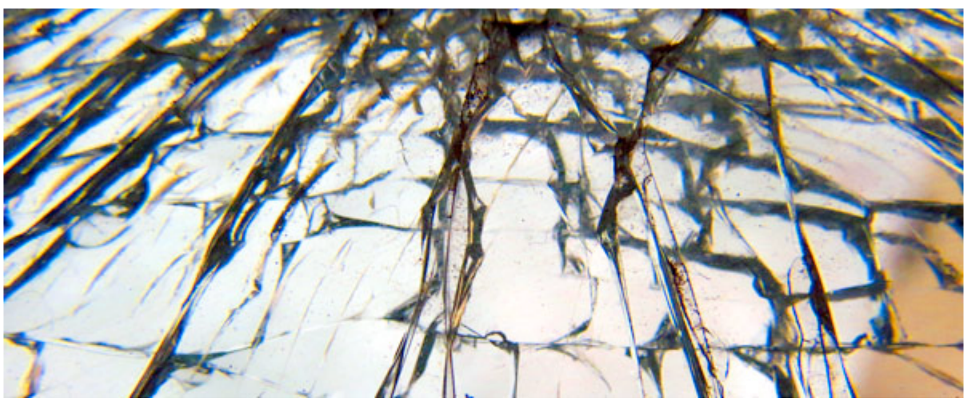
Common collection methods include individual fiber collection using tweezers or vacuuming an area and sorting the materials at the laboratory.

Trace evidence can also be gathered by tape lifting, however, this is not ideal due to the destructive nature of adhesives.

Samples that potentially contain fibers should be separately bagged to prevent cross-contamination.

References to collection and storage of fiber and hair evidence can be found in the Quality Documents Program, Laboratory Physical Evidence Bulletin #4. (http://www.nfstc.org/download/65)

Glass - Glass can be used to gather evidence, for example collecting fingerprints or blood from a broken window; however, glass also has a place in the trace evidence section. Broken glass fragments can be very small and lodge in shoes, clothing, hair or skin. Gathering glass fragments from a crime scene can be valuable in determining end-use or connecting people and objects to places. For example, windshields have a different color and composition than a drinking glass or a lead crystal vase, so glass fragments on an individual's clothing could be compared to those collected at a hit-and-run scene to determine if that individual was present.



Windshield fracture pattern. (Courtesy of NFSTC)

Collection: Trace examiners may use magnification and light to find glass fragments on clothing, an individual or at a crime scene and extract those using tweezers. Tape may also be used to collect glass samples, but the residue left from the adhesive makes this a less desirable collection method.

References to collection and storage of glass can be found in the Quality Documents Program, Laboratory Physical Evidence Bulletin #3. (http://www.nfstc.org/download/65)

Paint - Painted surfaces are everywhere and the wide variety of layered colors, lusters and types often make paint high-value as evidence. For example, paint transferred when one vehicle hits another vehicle, a pedestrian or a building can be matched to potentially identify the car in question. In a property crime where a tool is used to break into a building, paint transferred to or from the tool can connect the tool to the location. Analyzing automotive paint can identify the make, model and sometimes the year of a vehicle.

Collection: To collect paint, investigators document the scene, then peel off, or excise, small amounts of paint from the source, being careful to gather all layers. Samples as small as one square millimeter can be used for testing. For a car crash scene, paint samples from the point of contact would be photographed, collected and stored in such a way as to protect the edges for further examination. This is particularly important when examining for fracture matches.

Paint samples are typically collected by scraping small sections down to the metal or original surface or using tweezers to collect chips already dislodged.

References to collection and storage of paint can be found in the Quality Documents Program, Laboratory Physical Evidence Bulletin #2. (**http://www.nfstc.org/download/65**)

Who Conducts the Analysis

Most large laboratories or laboratory systems have a trace evidence section. Analysts have a variety of backgrounds, but most require a degree in a natural science with additional certification or additional study in chemistry, particularly if the primary degree is not in chemistry. Certification is generally conferred on an individual who has achieved specific education, training, experience and performance on competency tests as designated by the certifying organization. Some areas of trace evidence have individual certification programs, which are facilitated by professional associations and boards. The American Board of Criminalists certifies trace examiners using a General Knowledge Exam (GKE) and specialty exams in fibers, hair and glass.

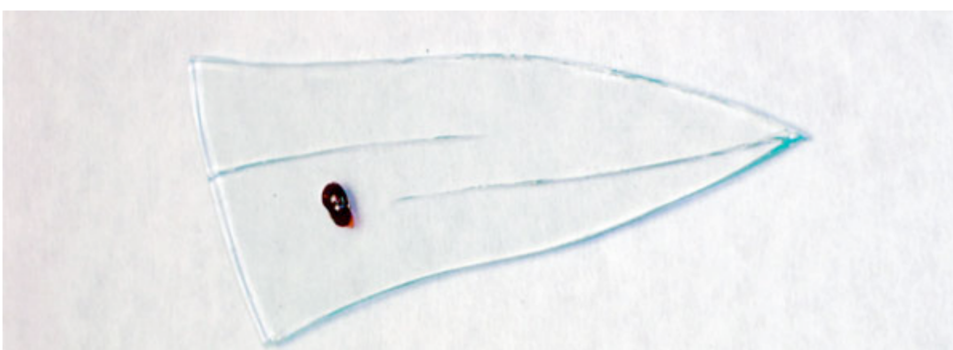
How and Where the Analysis Is Performed

Since trace evidence covers a wide variety of subcategories, there is similar variety in the testing that is performed. Specialized testing may be done outside of the local laboratory at regional or national facilities. The type of test performed and the range of information provided vary by the type of evidence tested. For example, analysis of a strand of hair may yield information on the race and general health of the donor, while analysis of a paint sample would likely yield the manufacturer of the paint and its commercial use.

Hair: Hair samples are tested primarily by microscopic comparison and chemical analysis. Microscopic comparison identifies the shape, color, texture and other visual aspects of the sample, while chemical analysis indicates the presence of toxins, drugs, dyes and other chemicals. In some cases hair is subjected to DNA analysis. Learn more about DNA (http://www.forensicsciencesimplified.org/dna/index.htm)

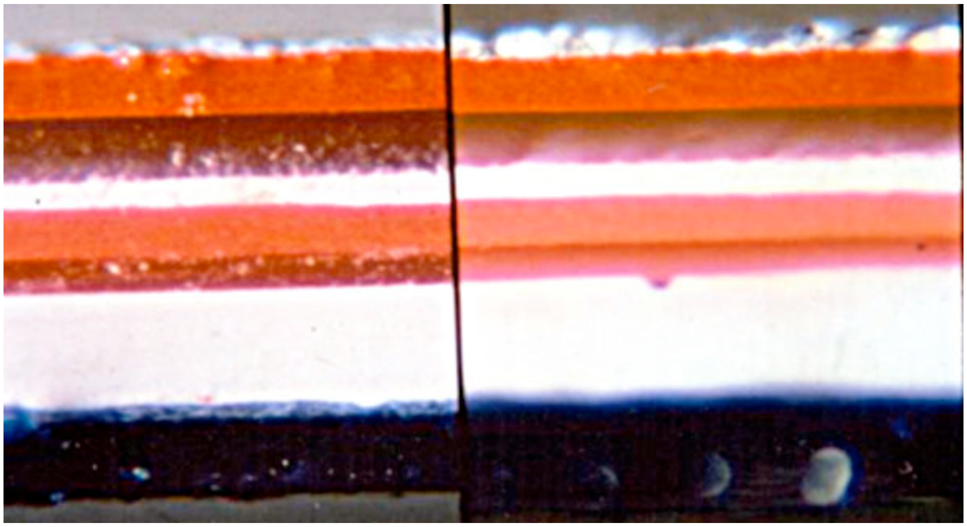
Fibers: Trace evidence analysts often have only mere strands to work with. From these strands, fiber testing is done using high-powered comparison microscopes to compare texture and wear in a side-by-side assessment. Chemical analysis can determine the chemical composition of the fibers. In the case of synthetic fabric or carpet, this information can be used to trace the product to the manufacturer using standards databases, further enhancing the probative value of the evidence.

Glass: Glass can yield valuable information through fracture marks, lines and patterns. Testing for unique characteristics such as color, optical properties and density can determine the type of glass, for example a window pane, vase or glass bottle. A detailed elemental analysis, including specific impurities, can be done using laser ablation mass spectrometry, induction-coupled mass spectrometry, X-ray fluorescence or other instruments.



Glass shards can be used for sourcing the glass and also to collect potential biological evidence. (Courtesy of NFSTC)

Paint: Powerful comparison microscopes are used to compare colors, thickness and layer patterns, and luster or to match fragments and tears. Chemical testing, such as Pyrolysis Gas Chromatography (PYGC) can be used to determine chemical composition, colors and pigments and other qualities.



Microscopic comparison of paint samples can show layers of paint, primer, coatings, scratches and other damage that can uniquely match two pieces or otherwise provide class identification information. (Courtesy of NFSTC)

FAQs

What are the limitations of the analysis?

The analysis of trace evidence can reveal connections between people and places that may not have been readily apparent at first. Results are provided to investigators to identify leads or assist in piecing together a more revealing picture of what may have happened at a crime scene.

The discipline's primary limitation is that trace evidence can exclude an individual from an investigation but, unlike DNA testing for example, most trace evidence is unable to directly link or identify an individual or specific object. The results of examination are useful in narrowing down the possibilities for source and common origin via class characteristics and other properties.

How is quality control and quality assurance performed?

To ensure the most accurate analysis of evidence, the management of forensic laboratories puts in place policies and procedures that govern facilities and equipment, methods and procedures, and analyst qualifications and training. Depending on the state in which it operates, a crime laboratory may be required to achieve accreditation to verify that it meets quality standards. There are two internationally recognized accrediting programs focused on forensic laboratories: The American Society of Crime Laboratory Directors Laboratory Accreditation Board (http://www.ascld-lab.org/) and ANSI-ASQ National Accreditation Board / FQS (http://fqsforensics.org/).

The Scientific Working Group for Material Analysis (SWGMAT) (http://www.swgmat.org/) works to set quality guidelines across a variety of trace disciplines including glass, fiber, hair, paint and tape. These standards provide good laboratory practice for trace analysts.

What information does the report include and how are the results interpreted?

Because of the individualized nature of trace evidence fragments, there are often no significant statistics that would be used to determine the likelihood of accuracy, as would be found in DNA evidence. Without statistics, presentation of analysis and interpretation results can vary. In 2009, the SWGMAT presented an updated conclusion scale that combined work by individual scientists and international work groups (TES, 2009) (http://projects.nfstc.org/trace/2009/). Although not universally preferred by officers and members of the court, the effort to make probability statements clear and consistent is critical.

How does the conclusion scale work?

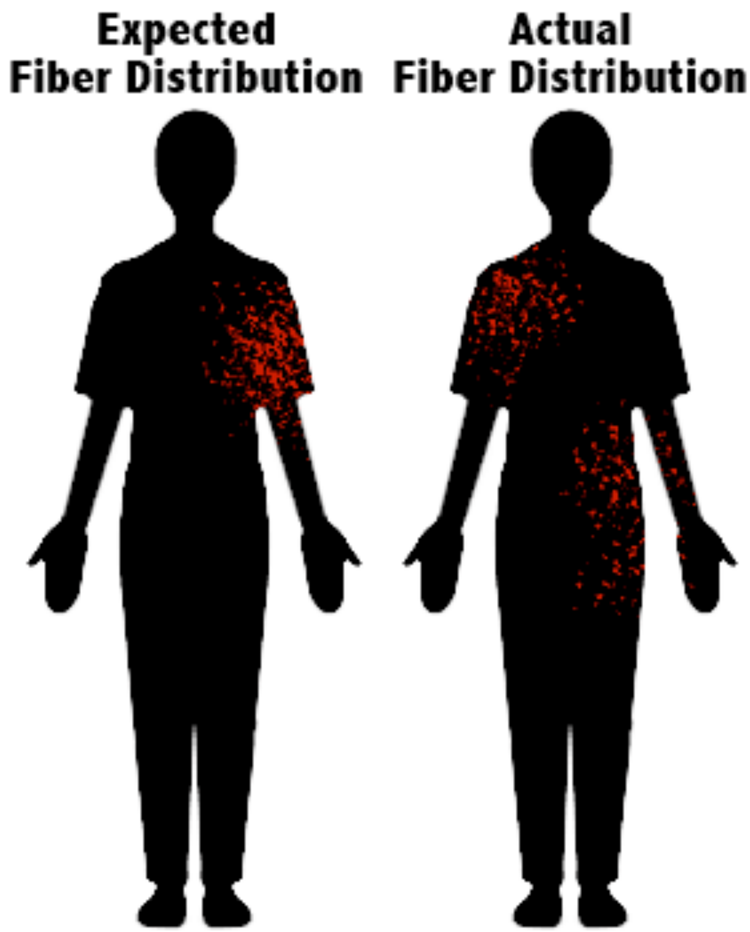
A trace evidence report should contain both the conclusion, conclusion scale definitions and the supplemental explanation of findings.

Trace Evidence Conclusion Scale

(introduced in 2009)

- **Identified** (Type I Association) - A positive identification; an association in which items share individual characteristics that show with reasonable scientific certainty that the items were once from the same source.
- **Very Strong Support** - An association in which items are consistent in all measured physical properties or chemical properties and share highly unusual characteristic(s) that are unexpected in the population of this evidence type.
- **Strong Support** (Type II Association) - An association in which items are consistent in all measured physical properties or chemical properties and share unusual characteristic(s) that are unexpected in the population of this evidence type.
- **Moderately Strong Support** (Type III Association) - An association in which items are consistent in all measured physical properties or chemical properties and could have originated from the same source. Because similar items have been manufactured or could exist in nature and could be indistinguishable from the submitted evidence, an individual source cannot be determined.
- **Moderate Support** (Type IV Association) - An association in which items are consistent in all measured physical properties and chemical properties so could have originated from the same source. This sample type is commonly encountered in our environment and may have limited associative value.
- **Limited Support** (Type V Association) - An association in which some minor variation exists between the known and questioned items that could be due to factors such as sample heterogeneity, contamination of the sample(s), or the quality of the sample. The items may be associated, but other sources exist with the same level of association.
- **Inconclusive** - No conclusion can be reached regarding the association between the items.
- **Elimination** - The items are dissimilar in physical properties or chemical composition and did not originate from the same source.

In addition, findings may be supported by verbal explanations and images depicting the likely and actual distribution of trace evidence. For example, if a crime victim claims that her assailant grabbed her left arm and stole her purse, fiber transfer from the attacker's clothing would be expected on her left side and sleeve. An image of the expected and actual fiber distribution patterns can be very helpful in a courtroom setting.



(Courtesy of NFSTC)

Are there any misconceptions or anything else about trace evidence that might be important to the non-scientist?

A common misconception of trace evidence is that a tiny piece of evidence can always be "matched" and directly identify an individual object. This is a rare outcome as the items examined in trace most often lead to identification of the evidence as part of a class. For example automotive paint may be found to be of the same type as the car in question, but not automotive paint from the car in question.

Another misconception is that every crime laboratory handles trace evidence. As a matter of fact, in the 2005 Census of Publicly Funded Forensic Crime Laboratories (http://www.bjs.gov/content/pub/pdf/cpffcl05.pdf), only 55% of laboratories handled trace evidence. The report does not break out the specialties within trace, however, and some specialties are most often performed at regional laboratories.

Common Terms

Bulk sample - A sample that is large enough to weigh.

Class characteristics - Measurable features of a specimen which indicate a restricted group source, but not traceable to an individual person or item. Class characteristics can determine things like automotive paint types, blood types of people or a collection of new Phillips head screwdrivers, but cannot produce a specific match or individual identification. This type of evidence may be used to narrow down a list of possible sources.

Fracture Match (sometimes called a Physical Match) - The examination of two or more objects either through physical, optical, or photographic means which permits conclusions as to whether or not the objects were either one original piece or were held or bonded together in a unique arrangement. The concept is similar to putting together the pieces of a jigsaw puzzle.

Glass - an inorganic product of fusion, cooled to a rigid condition. It is essentially composed by heating a mix of sand, limestone and soda, along with various impurities.

Individual Characteristics - Evidence that can be associated with a common source with a high degree of certainty. The probability the specimens are of common origin is so high as to defy mathematical calculations. Evidence associated with individual characteristics include fingerprints, DNA and striations on a bullet.

Microscopy - the use of or investigation with a microscope.

Reference Sample - A material of known physical characteristics authenticated by a certified procedure accompanied by or traceable to documentation.

Probative - potentially valuable and worthy of further testing and analysis evidence.

Pyrolysis - The decomposition of organic matter by heat.

Scanning electron microscope - type of electron microscope, designed for directly studying the surfaces of solid objects. This process produces a three-dimensional image of the surface of the object.

Paint - a manufactured liquid that dries to form a thin, hard coating. It is composed of carriers, pigments, modifiers, extenders and binders.

Primary transfer - The direct transfer of trace evidence from one object to another.

Radial fractures - A crack in a glass that extends outward like a spoke of a wheel from the point at which the glass was struck.

Soil profile - A vertical section through a soil showing the different horizons from the surface to the underlying parent material.

Trace sample - An amount so small that it cannot be weighed—although it may well be possible to establish its weight by means of quantitative chemical analysis.

Resources & References

Learn more about this topic at the websites and publications listed below.

Resources

National Institute of Justice Trace Evidence Symposium (http://projects.nfstc.org/trace/), 2007, 2009, 2011

FBI Laboratory Scientific Working Group for Material Analysis (SWGMAT) (http://swgmat.org/)

"Do Sweat the Small Stuff: Trace Evidence Can Make a Big Difference" (article) (https://www.ncjrs.gov/app/publications/abstract.aspx?ID=205066)

National Institute of Justice Forensic Databases (http://www.nij.gov/journals/258/forensic-databases.html)

References

American Board of Criminalists, Certification Program Overview (http://criminalistics.com/cert_ovw.cfm), (accessed July 31, 2012)

Firearms Examiner Training (**http://projects.nfstc.org/firearms/glossary.htm - I**), National Institute of Justice (online). (accessed July 31, 2012)

Laboratory Physical Evidence **BULLETIN #2**: "Collection of Paint Fragments (online)," Bulletin #3: "Collection of Glass Fragments (online)," and **BULLETIN #4**: "Collection of Fiber and Hair Evidence (online)," Quality Documents Program (**http://www.nfstc.org/download/65**) (accessed July 20, 2012).

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Saferstein, Richard. **CRIMINALISTICS: AN INTRODUCTION TO FORENSIC SCIENCE**, Pearson Education, Inc., Upper Saddle River, NJ (2007).

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Forensic Evidence Admissibility and Expert Witnesses

How or why some scientific evidence or expert witnesses are allowed to be presented in court and some are not can be confusing to the casual observer or a layperson reading about a case in the media. However, there is significant precedent that guides the way these decisions are made. Our discussion here will briefly outline the three major sources that currently guide evidence and testimony admissibility.

The *Frye* Standard – Scientific Evidence and the Principle of General Acceptance

In 1923, in *Frye v. United States*[1], the District of Columbia Court rejected the scientific validity of the lie detector (polygraph) because the technology did not have significant general acceptance at that time. The court gave a guideline for determining the admissibility of scientific examinations:

Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while the courts will go a long way in admitting experimental testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be **sufficiently established to have gained general acceptance** *in the particular field in which it belongs.*

Essentially, to apply the "*Frye* Standard" a court had to decide if the procedure, technique or principles in question were generally accepted by a meaningful proportion of the relevant scientific community. This standard prevailed in the federal courts and some states for many years.

Federal Rules of Evidence, Rule 702

In 1975, more than a half-century after *Frye* was decided, the Federal Rules of Evidence were adopted for litigation in federal courts. They included rules on expert testimony. Their alternative to the *Frye* Standard came to be used more broadly because it did not strictly require general acceptance and was seen to be more flexible.

[1] 293 Fed. 1013 (1923)

The first version of Federal Rule of Evidence 702 provided that a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

a. the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
b. the testimony is based on sufficient facts or data;
c. the testimony is the product of reliable principles and methods; and
d. the expert has reliably applied the principles and methods to the facts of the case.

While the states are allowed to adopt their own rules, most have adopted or modified the Federal rules, including those covering expert testimony.

In a 1993 case, *Daubert v. Merrell Dow Pharmaceuticals, Inc.,* the United States Supreme Court held that the Federal Rules of Evidence, and in particular Fed. R. Evid. 702, superseded *Frye's* "general acceptance" test.

The *Daubert* Standard – Court Acceptance of Expert Testimony

In *Daubert* and later cases[2], the Court explained that the federal standard includes general acceptance, but also looks at the science and its application. Trial judges are the final arbiter or "gatekeeper" on admissibility of evidence and acceptance of a witness as an expert within their own courtrooms.

In deciding if the science and the expert in question should be permitted, the judge should consider:

- What is the basic theory and has it been tested?
- Are there standards controlling the technique?
- Has the theory or technique been subjected to peer review and publication?
- What is the known or potential error rate?
- Is there general acceptance of the theory?
- Has the expert adequately accounted for alternative explanations?
- Has the expert unjustifiably extrapolated from an accepted premise to an unfounded conclusion?

[2] The "Daubert Trilogy" of cases is: **DAUBERT V. MERRELL DOW PHARMACEUTICALS**, **GENERAL ELECTRIC CO. V. JOINER** and **KUMHO TIRE CO. V. CARMICHAEL**.

The *Daubert* Court also observed that concerns over shaky evidence could be handled through vigorous cross-examination, presentation of contrary evidence and careful instruction on the burden of proof.

In many states, scientific expert testimony is now subject to this *Daubert* standard. But some states still use a modification of the *Frye* standard.

Who can serve as an expert forensic science witness at court?

Over the years, evidence presented at trial has grown increasingly difficult for the average juror to understand. By calling on an expert witness who can discuss complex evidence or testing in an easy-to-understand manner, trial lawyers can better present their cases and jurors can be better equipped to weigh the evidence. But this brings up additional difficult questions. How does the court define whether a person is an expert? What qualifications must they meet to provide their opinion in a court of law?

These questions, too, are addressed in **Fed. R. Evid. 702**. It only allows experts "qualified … by knowledge, skill, experience, training, or education." To be considered a true expert in any field generally requires a significant level of training and experience. The various forensic disciplines follow different training plans, but most include in-house training, assessments and practical exams, and continuing education. Oral presentation practice, including moot court experience (simulated courtroom proceeding), is very helpful in preparing examiners for questioning in a trial.

Normally, the individual that issued the laboratory report would serve as the expert at court. By issuing a report, that individual takes responsibility for the analysis. This person could be a supervisor or technical leader, but doesn't necessarily need to be the one who did the analysis. The opposition may also call in experts to refute this testimony, and both witnesses are subject to the standard in use by that court (*Frye, Daubert*, Fed. R. Evid 702) regarding their expertise.

Each court can accept any person as an expert, and there have been instances where individuals who lack proper training and background have been declared experts. When necessary, the opponent can question potential witnesses in an attempt to show that they do not have applicable expertise and are not qualified to testify on the topic. The admissibility decision is left to the judge.

Additional Resources

Publications:

Saferstein, Richard. **Criminalistics: An Introduction to Forensic Science**, Pearson Education, Inc., Upper Saddle River, NJ (2007).

McClure, David. Report: Focus Group on Scientific and Forensic Evidence in the Courtroom (online), 2007, https://www.ncjrs.gov/pdffiles1/nij/grants/220692.pdf (accessed July 19, 2012)

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