

# Chapter 68

## Criminalistics

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Stages of Evidentiary Analysis  
Classification of Physical Evidence

Challenges to Criminalistics Evidence

The principles of forensic evidence examination can be applied to recognize, collect, preserve, examine, and interpret various types of physical evidence associated with a crime scene. The crime scene can be a body, a location, or a vehicle. The diverse application of the scientific method, commonly referred to as “criminalistics,” provides important, objective information during a case investigation. Analysis of physical evidence may also supply investigative leads through the identification of unknown materials, the comparison to known standards, or by the use of analytical databases to determine a potential source. Criminalists today employ a wide range of tests from microscopic examination to the integration of mass spectrometry with gas or liquid chromatography and computerized image enhancement. Since there are many specialties within criminalistics, the specific analytical approaches, testing procedures, and techniques will vary. The goal of any criminalistics examination, however, is to provide scientific, factual data that, for example, can link a suspect to a case or exonerate the suspect. Cases often go unsolved without objective scientific data to support or to disprove a theory. The results of objective analysis of physical evidence can provide necessary facts that a jury can use to determine the guilt or innocence of a suspect.

Since the divisions of criminalistics are so varied, there are many ways evidence can be classified and analyzed. These classifications commonly include separation by: (1) physical state of the evidence; (2) origin of the evidence, such as evidence from the victim, a witness, or from the suspect; (3) type of evidence examination that is required, such as DNA evidence or latent fingerprint evidence; (4) type of crime, such as homicide evidence or sexual assault evidence; and (5) composition of the evidence, such as biological evidence or chemical evidence.

While criminal investigators and legal practitioners may classify criminalistics evidence differently, the basic approach to the analysis of physical evidence remains the same. Laboratory analyses conducted will ultimately be determined by the nature of the physical evidence and whether evidence items and control samples can be traced to a common origin. For example, evidence removed from the clothing of a homicide victim may be examined to determine the anthropological and body origins of the hair; such information may provide valuable investigative leads for

the investigators. More importantly, by microscopic comparison of the questioned hair sample to a known hair sample, one can eliminate or include that person as a potential suspect. On the other hand, it may be most appropriate to compare the DNA profile obtained from that hair with a suspect to provide an individualizing, positive linkage to the contributor of the hair.

### STAGES OF EVIDENTIARY ANALYSIS

The central “dogma” of criminalistics examinations involves the recognition, identification, comparison, individualization, and interpretation of evidence. In some cases, after these analytical procedures, reconstruction of the incident events may be required.

Recognition requires that the criminalist have sufficient knowledge and experience to separate inconsequential items from potential physical evidence. This process also includes pattern recognition and documentation of physical characteristics of the objects examined. If the evidentiary nature of an object or pattern is not recognized, information that might have been gained from that evidence will be lost.

Identification uses patterns and class characteristics of the material to determine what the evidence is. These class characteristics may be physical, chemical, or biological in nature. Many types of analysis may be involved to complete these observations. At this stage of the testing process, the criminalist will utilize the most nondestructive and straightforward methods to reach a conclusion. It is also important at this stage to consume or alter a sample as little as possible. Thus, screening tests, instrumental analysis that requires little sample preparation, and microscopic examinations are the common methods employed for identification of physical evidence.

Classification involves the use of further examinations to gain sufficient information to place the evidence in a specific category. This classification may be achieved by comparison to a set of known standards from a database or reference collections, or to a known sample submitted for that purpose. It is at the stage of classification that evidence may be excluded by showing it differs significantly from the known material. Techniques for classification include

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a variety of instrumental, biochemical, microscopic, and physical methods. When the evidence compares positively with the known standard, analysis may continue to the next stage. However, in many cases the nature of the evidence itself or a legal requirement prevents analysis beyond the level of classification. While this fact causes some confusion and concern among those not conducting criminalistics examinations, it is a reality of the discipline.

When individualization of evidence is possible, it means that evidence can be attributed to a unique source. For example, criminalists make individualizations by comparing fingerprints and other imprint evidence to link that fingerprint or imprint with one and only one source. Forensic DNA analysis may approach individualization in some cases when the profiles obtained and the probability of occurrence is calculated to be sufficiently unique in humans; some laboratories have identified a frequency of occurrence below which an individualization is stated.<sup>1</sup>

Reconstruction does not involve specific analytical techniques, but uses logical analysis of data gained during those procedures to determine the sequence of events or to reconstruct the nature of an incident. Laboratory data is often combined with other information collected during an investigation through a logical, systematic process to arrive at the reconstruction.

Figure 68-1 shows the process of criminalistics analysis and its relationship to other facets of an investigation.

## CLASSIFICATION OF PHYSICAL EVIDENCE

It is often useful to classify physical evidence according to its nature by dividing evidence into the following types: transient evidence, conditional evidence, pattern evidence, transfer evidence, and associative evidence.

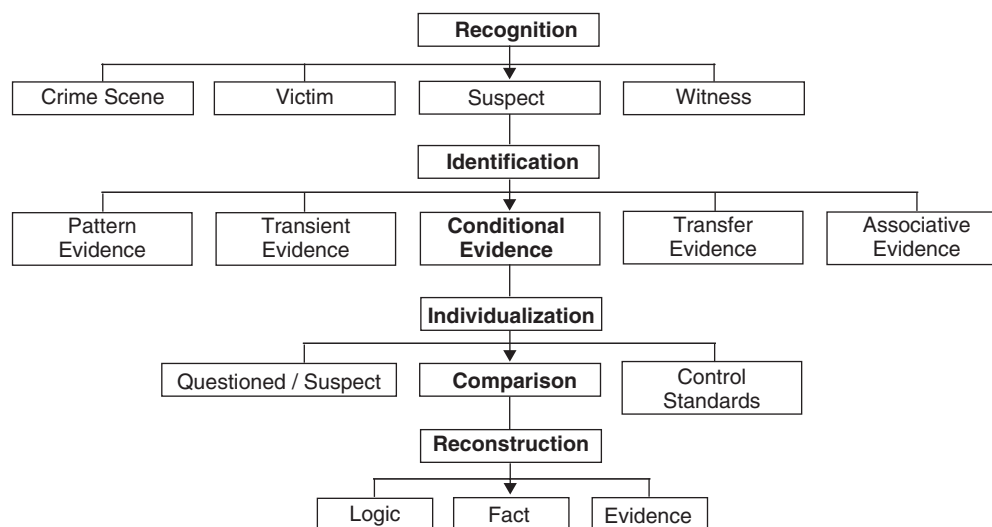
## Transient Evidence

Transient evidence, as the name implies, includes those materials and patterns that are temporary in nature. These types of evidence are easily lost or changed by time or circumstances. Examples of transient evidence include heat, odor, surface imprints, rigor mortis, color of bloodstains, and gaseous products, such as smoke. Because transient evidence does readily disperse or change, this type of evidence is often lost unless witnesses or first responders to a scene are acutely aware of its importance and take appropriate steps to document or preserve such evidence.

For example, in one case, the first fire responders to a factory fire noted the large amount of dense, dark smoke and an accelerant-type odor when they arrived at the scene. Once the inception stage of the fire was over, the transient evidence was quickly consumed during the free-burning stage. The acute observations of the firefighters provided factual information useful in the prosecution of an arson-murder case. In another case, the amount of blood present upon arrival by first responders was critical information. The forensic scientist used the witness statements and the initial scene photographs to reconstruct the crime. The victim's husband claimed that he had called 911 as soon as she shot herself and then moved her body from the bed to the floor. The bed and a part of the pillow on the side of the bed where she had been shot were soaked with blood at the time paramedics arrived. Based on the amount of blood that had flowed from the body to stain the bed, it was determined that the victim had been shot some time earlier than alleged by her husband.

## Conditional Evidence

Events or activities of the victim or suspect may result in conditional evidence at the scene or on a body. As with transient evidence, some categories of conditional evidence



**Figure 68-1** Relationships among various steps in the analysis of physical evidence.

may be altered by persons, time, or environmental factors. The temperature of a body, the extent of rigor mortis, and the position of the body are all conditions that affect interpretations of the scene. Natural environmental changes can also affect conditional evidence. The impact of environmental factors such as fly larval development and the populations of insects on investigation is well documented.<sup>2</sup> These organisms and the location of the scene are important considerations when interpreting case data and may, themselves, alter significantly the condition and appearance of the physical evidence. Conditional evidence can be key in reconstructing a crime, distinguishing accidental or intentional staging from other causes, or determining the possible sequence of events associated with an incident.

In another case, when a victim's body was found in her bedroom with the air conditioner on high, first responders left the door to the room open. They also turned off the air conditioner because it was too cold to work in the room. By the time the medical examiner and the laboratory scientists arrived at the scene, the ambient temperature of the room had increased notably. This alteration of the scene clearly had a negative impact on the ability of the medical examiner to estimate the time of death based on the body temperature. Thus, the forensic scientist had only witness statements and photographs for scene reconstruction.

## Pattern Evidence

Pattern evidence includes a large, diverse group of physical patterns. This type of evidence can be produced by static or dynamic contact between two objects, a person and an object, or two persons. Physical patterns from direct contact can be used to determine the type of contact or mechanism that created the pattern. Commonly encountered pattern evidence includes bloodstain patterns, fracture and other damage patterns, burn patterns, patterns of residue deposits, imprints and impressions, patterns of scene activity, and *modus operandi*. Regardless of the type of pattern encountered, there are six steps in the analysis of pattern evidence: (1) recognition of the pattern; (2) documentation of the pattern; (3) enhancement of the pattern; (4) identification of the pattern; (5) comparison of the pattern; and (6) determination of the mechanism of transfer.

Recognition of pattern evidence requires careful observation as part of a logical, systematic approach to the analysis of the crime scene. In addition, experience plays a major role in the ability to perceive and to distinguish similar patterns. Recognition of patterns at a crime scene may play an important role in providing investigative leads. It should be noted that the absence of a pattern may also be significant in case reconstruction. Patterns may also assist investigators to limit false theories based on other information gained from witnesses. Distinguishing between an imprint and an indentation, for example, resulted in controversy during a high-profile criminal case.<sup>3</sup> Thorough observation and careful documentation of the scene at the time of the incident and prior to the admitting of numerous technicians and detectives who walked around the scene might have eliminated this issue during trial. Pattern recognition and

preliminary examination can also result in distinguishing between patterns created by types of objects or weapons; this distinction is particularly important when manner and cause of death become an issue. Damage to clothing and human remains caused by animals may often appear to be significant indicators of *modus operandi* to the uninitiated. Marks made by humans that can be detected on bodies would include bite marks, fingerprints, hand prints, and scratch marks caused by nails. The patterns produced by humans demonstrate characteristics different from animal bite or claw marks and insect damage when examined properly. Weapon marks can be distinguished from artificial marks or postmortem damage upon similar careful analysis.

Recognition also involves the determination of whether a pattern is the result of a primary, sometimes called a "direct," transfer or of a secondary action. Activities subsequent to the initial incident, such as transport of a body or evidence, can alter the original pattern, create additional patterns, damage evidence, or transfer chemical residue patterns, such as gunshot residue (GSR). Failure to prevent or to recognize those patterns as secondary in nature could have a serious impact on an incident investigation.

Key to the proper identification and interpretation of pattern evidence is complete and detailed documentation. Documentation in the form of written notes, measurements, photographs, video, and sketches all help to place the pattern evidence in its proper perspective for comparison and reconstruction purposes. In general, thorough photographic documentation must include overall and close-up views of the pattern and its components; these photographs must be taken with and without a scale. This thorough documentation of the patterns prior to alteration of the scene or evidence can help determine if secondary patterns have been produced or if patterns have been altered during collection and transport of the physical evidence. In addition, since many types of pattern evidence may be altered or destroyed by subsequent laboratory analysis, thorough documentation of patterns prior to removing samples provides a complete record for review by other experts or for reconstruction. Since pattern evidence can be a vital part of a case presentation, photographic documentation of the original pattern provides demonstrative evidence for court purposes.

Laboratory techniques applied to the recognition of pattern evidence usually involve macroscopic and low-power microscopic observation of the patterns themselves. In some cases, patterns are enhanced by the use of alternative light sources that will cause some materials to fluoresce at various wavelengths, with or without chemical enhancement. Chemical enhancement techniques have also been successfully used in many situations to develop details of blood and body fluid patterns and for some chemical residues.<sup>4</sup>

Identification is the next step in pattern analysis. Examination of the pattern itself and of photographs using an appropriate scale helps the criminalist identify the possible source of the evidence. Patterns that demonstrate regular, mechanical macroscopic or microscopic characteristics are readily identified as marks made by a tool. Tool mark patterns result from the impact of a manufactured

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object with a surface. Based on this description, tool mark patterns could include ligature marks associated with a garment or rope, tire marks, finger marks, or typical “tools,” such as saws and screwdrivers. Additional examinations, such as higher magnifications using a comparison microscope or scanning electron microscopy (SEM), may be warranted to examine details of impressions or to look at microscopic morphology and minute configurations. While it is often easy to identify a gunshot wound from its macroscopic appearance, for example, in some cases microscopic examination of the excised wound for the presence of gunpowder or metallic residue may be necessary for scientific confirmation. SEM and other microscopic techniques can also help the scientist distinguish whether a specific type of tool caused damage to an object.

The final stage in pattern analysis involves interpretation and comparison of the identified patterns. The experienced criminalist may offer preliminary interpretations based on observations during the earlier steps in the analysis. However, that examiner must have an open mind and be willing to modify any conclusions made prior to extensive examination and testing. Appropriate pattern interpretation requires extremely careful and detailed study. Further chemical, physical, or photographic enhancement of the evidence may be required at this stage for complete interpretation or to effect a comparison. This enhancement can provide additional detail not considered during preliminary examinations. If a known exemplar is submitted for comparison to the questioned pattern, such as with footwear patterns, the same detailed study must be carried out on the exemplar prior to comparison.

Once necessary examinations and comparisons are made, a final reconstruction as to the mechanism and causation of a pattern is offered. These conclusions must always follow the guidelines established by science and logic.

### Transfer and Trace Evidence

The most common type of evidence classification is referred to as transfer evidence. Based on Locard's exchange principle,<sup>5</sup> transfer evidence is among the most diverse and the most useful types of physical evidence in investigations. Trace evidence is material present in small quantity or size. Trace materials are found at scenes, on bodies, or on other pieces of physical evidence. While the terms trace and transfer evidence are often used interchangeably, there are instances in which evidence may be deposited without direct contact transfer. However, these distinctions are generally immaterial for the purposes of recognition, documentation, or laboratory analysis, but may be significant during case reconstruction.

Transfer evidence is often subdivided into several categories. Many categorization schemes are used, often based on the different uses of transfer evidence or the perspective from which the analysis is viewed. A transfer evidence classification system based on the general origin of the evidence would include: (1) biological evidence; (2) physiological evidence; (3) chemical evidence; (4) polymers; (5) mineralogical evidence; and (6) construction materials. Table 68-1 lists

<b>Biological Matter</b>	Metals
Grass	Natural and synthetic crystals
Leaves	
Wood	<b>Physiological Evidence</b>
Pollen	Blood
Fruits	Semen
Seeds	Urine
Hairs	Fecal material
	Tears, milk, bile
<b>Chemical Evidence</b>	Tissues, including bone
Toxicological—drugs, alcohol, poisons, other chemicals	Hair
Writing materials—ink, dye, oil, wax, paper	<b>Polymeric Evidence</b>
Household products—cleaners, acids, caustic powders, insecticides	Fibers
Explosives	Paints and finishes
Accelerants	Plastics
<b>Mineralogical Evidence</b>	<b>Construction Materials</b>
Soil	Concrete
Minerals and ores	Cement
Sands	Plasters
Glass	Asphalts
	Wood
	Paints and finishes
	Nails, screws, brads, and fasteners

**Table 68-1** Examples of trace and transfer evidence

some examples of those evidence categories. Trace and transfer evidence has been challenged in court recently as not meeting scientific muster or as having the potential to prejudice a jury that might place more weight on that evidence than is appropriate. A brief description of the analysis of some of the commonly encountered trace materials may provide some insight into the application of analytical techniques to specific types of evidence and the potential value of transferred materials.

### Biological Evidence

Biological evidence includes materials that are vegetative or animal in origin and can often be identified and associated with possible sources. The identification of biological substances and comparisons of questioned with known samples can provide useful information for investigative leads or provide cumulative evidence in circumstantial cases. Since the transfer of biological evidence is a common occurrence, many investigators or laboratory analysts may not recognize the value of a particular specimen. Even commonly occurring materials, however, can provide a link between the suspect and the victim or the crime scene or provide valuable information for case reconstruction. In addition, evidence such as pollen is of such a small size that the presence of these materials may be overlooked. In one case, microscopic algae embedded in the fibers of the tee-shirt from a suspect in a homicide case was analyzed by compound and scanning electron microscopy. The presence of these algae led to an association with a pond in the back yard of the victim's house. The murder weapon containing the victim's hair and blood was found in that pond after the association by this transfer evidence.

Recent advances in biotechnology have led to the development of techniques for analysis of plant DNA. Comparisons of DNA profiles obtained from questioned plant materials with known plant samples or databases have resulted in successful individualization, much like the process of human DNA comparisons.<sup>6</sup> Research is currently being carried out at several forensic laboratories to validate DNA testing procedures on marijuana and other plant species.

### Physiological Evidence

Evidence of physiological origin is among the most significant evidence available for identification, individualization, and association to an individual. Although each type of evidence in this category has its limitations, physiological materials often can provide important investigative leads, support a victim's or suspect's account of an incident, or link a victim, suspect, scene, and/or object.

**Hair** Hairs are often found associated with a victim, suspect, or a crime scene because they are shed as part of the growth cycle of the hair or exchanged during contact and altercation. Hair has the same basic structure whether it comes from a human or some other animal. Chemically, all hair is composed of the protein keratin; thus, current instrumental techniques are not useful to the criminalist in identifying a hair as human in origin. However, microscopic features of hairs can be significantly different. It is the macroscopic and microscopic examination of this basic structure that allows the criminalist to differentiate the animal origin of the hair and, if human, its body origin. All growing hairs have a root, anchored in the hair follicle, a shaft, and a tip. Microscopic examination shows a further division of the hair into three portions: the cuticle, or outer layer; the central medulla; and the cortex, the layer between the medulla and cuticle that contains various structures, such as pigment granules and air spaces. Hair evidence may be damaged or some portions of the hair absent when found on other items or at the scene.

Most hairs that are not of human origin can be identified by examination of the microscopic characteristics of the hair at relatively low magnification. Animal hairs typically demonstrate regular cuticle and medullary patterns, have a relatively wide medulla in comparison to the hair width (often greater than half the width of the hair), and may show banding or other distinct pigment distribution. With sufficient experience and training, forensic microscopists can identify the species of origin of many animal guard hairs. Human hairs, on the other hand, usually demonstrate a relatively thin, irregular cuticle, a narrow or even absent medulla, and, if untreated, an unbanded color appearance. Additional examination of the diameter, cross-sectional shape, and pigment distribution in a human hair may give an indication of the anthropological classification (Caucasoid, Negroid, or Mongoloid). Additional microscopic features of diameter variation, shape, texture, and appearance may lead to identification of the hair as originating from the head, pubic region, or other body origin.

If known hairs are submitted for comparison purposes, such as in a sex crimes evidence kit, microscopic comparison

can be conducted. This process involves a painstaking examination of a significant number of known hairs<sup>7</sup> from the root end to the tip end, noting the structure, distribution, and appearance of many microscopic characteristics and structures. It is important to examine a representative sample of known hairs so that the natural variations present within and between hairs are well documented. Unknown hairs are mounted and a similar microscopic examination completed on those hairs. If no gross differences are noted between the known and questioned hairs, microscopic comparison using a double stage comparison microscope follows. If microscopic characteristics noted in the questioned hair fall outside the range of characteristics found in the known sample, the scientist can exclude the known as a source of the questioned hair. If all microscopic characteristics are similar to those demonstrated by the known hair, that known source cannot be excluded. When performed correctly, the process of hair comparison is a long, time-consuming examination. By its nature, microscopic hair comparisons *cannot* link a hair to a particular person or animal.

It cannot be stated strongly enough that microscopic examination of hairs does not serve as a positive means of individualization. Criminalists must be careful not to imply individualization and should make this clear throughout their testimony. Recent highly publicized instances of hair examiners testifying beyond the limitations of the science have made many skeptical of the value of microscopic hair comparison.<sup>8</sup> Fears that a jury will misinterpret the findings when testimony about hair comparisons is offered have led many attorneys to demand the exclusion of this "prejudicial" evidence. However, when hair comparisons are correctly conducted, they can provide valuable leads for investigators. Hair comparisons are also useful as corroborating or excluding evidence.

If a microscopical hair comparison cannot exclude an individual as the source of a hair, more individualizing tests may be possible. If the hair has a root containing sufficient cellular material, nuclear DNA STR profiles may be developed and compared to the possible source. If insufficient cellular material is present or the hair is a fragment, nuclear DNA testing cannot be performed. However, mitochondrial DNA testing can be conducted on hair shafts. Because mitochondria, unlike nuclear DNA, are generally inherited from the mother only, the mtDNA profile will not provide the same level of individualization as nuclear DNA analysis. However, statistics indicate that between 10% and 20% of hairs found to be microscopically similar will demonstrate dissimilar mtDNA sequences.<sup>9</sup>

**Blood and Body Fluids** The potential for blood or body fluids to provide individualizing information about the origin of those samples is well known. Advances in DNA technology allow analysis of minute quantities of fluid or tissue. Most physiological materials are suitable for DNA typing. Polymerase chain reaction (PCR) amplification of STR loci provide a valuable tool to the forensic laboratory, since analysis can be conducted in a short period of time. In addition, samples that are degraded may also give reliable

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DNA profiles using this method. Even small amounts of physiological materials on clothing, jewelry, and other items have provided STR profiles.<sup>10</sup> Because of its sensitivity, STR analysis has been the procedure most commonly utilized in the examination of old, unsolved cases or for postconviction testing.

Before DNA testing can be conducted, however, physiological samples should be identified whenever possible. This is especially important if genetic markers will be used in a case reconstruction. Use of alternative light sources has been shown to be an effective means of locating physiological stains for identification. After macroscopic search for possible body fluid stains, identifying a sample involves a screening test and, when available, a confirmatory test. Absolute identification of blood or a body fluid stain cannot be made based on a screening test alone. The value of a screening test is its ability to distinguish materials that are suitable for further testing.

Once a sample has been identified as blood, semen, saliva, tissue, etc., if sufficient sample exists a species test should also be conducted. Commercially available rapid immunoassay systems for the identification of human hemoglobin, for example, are extremely sensitive and consume very little material. This classification by species in addition to any human DNA quantitation may be information necessary to obtain warrants for known samples from a suspect. Testing a sample for human origin prior to DNA extraction will save time and resources if the results are negative for human blood.

Highly degraded physiological samples and samples such as bone tissue have been successfully typed using mtDNA analysis.

### Chemical Evidence

Chemical evidence is among the most prevalent in criminalistics laboratories. Forensic chemistry involves the identification of various organic and inorganic materials, including accelerants, explosives, gunpowder residue, drugs, toxic substances, and many other trace materials. The number of recent incidents involving the collection of “white powders” as suspected infectious biochemical weapons illustrates the complex process of analysis of an unknown chemical substance. Once these materials are found not to contain harmful biological agents, such as anthrax, the trace amounts of chemical evidence from those hoax cases are analyzed microscopically and instrumentally. Several different procedures must be utilized before identification of these unknown “white powders” can be effected. Infrared spectroscopy and gas or liquid chromatography coupled with mass spectrometry is usually employed to analyze complex mixtures or identify unknown chemicals. In some instances, quantitation of chemical residues may be important for reconstruction or developing new investigative leads.

**Gunpowder Residue** Burned and partially burned gunpowder, gases, and soot are released when a weapon is discharged, due to the detonation of the primer and gunpowder in the ammunition. Some of these materials are propelled with the projectile, some are blown back onto

the shooter. Deposits of gunshot residue (GSR) may contain components of primer, lubricant, propellant, or ammunition metals. Analytical techniques such as AA, ICP, and SEM/EDX can be used to detect the GSR collected from the hands or clothing of the shooter or victim. In addition, various chemical color tests for those components and infrared photography can be used on target surfaces to estimate the approximate distance between the barrel of the weapon and the target surface.

Historically, GSR was detected on swabbings of hands or surfaces using atomic absorption (AA) methods. Instrumental analysis is now carried out in most laboratories by ion coupled plasma (ICP) techniques. ICP is favored because of its greater sensitivity and more linear calibration. Levels of elements composing primers, typically lead, barium, and antimony, are determined and compared to negative control swabs. High levels of these elements may indicate that gunshot residue is present. However, ICP alone is not conclusive proof that someone discharged a firearm.

SEM analysis of adhesive disks collected from hands or target surfaces can sometimes yield more conclusive results for GSR. SEM/EDX can provide elemental analysis and reveal the morphology of a GSR particle. The combination of a particle possessing characteristic morphology with the presence of lead, barium, and antimony can be interpreted as the presence of GSR. The identification of GSR on a sample from a person's hands only indicates that the person tested might have fired a weapon. GSR can transfer to another surface either through direct contact with the weapon or as airborne particles. Thus, if the individual handled a weapon or was in close proximity when a weapon was discharged, GSR could be deposited in this manner.

### Polymer Evidence

**Fibers** Fiber transfer evidence is commonly encountered in many types of cases. The likelihood that fibers will transfer depends on the type of fiber, the type of the fabric source, and the nature of the contact surface. Animal fibers, for example, have a tendency to remain adhered to another fabric due to the protruding hair scales of the fiber and electrostatic attraction. Transfer may be through direct (primary) or indirect (secondary) contact.

Fibers are of two general types: natural fibers that occur in the environment or have been used in manufacturing, and synthetic fibers. Fiber examination may involve numerous steps and analyses, depending on the type of fiber and the instrumentation available to the laboratory. Some of the techniques of fiber analysis are destructive; therefore, many laboratories do not conduct those tests in order to preserve the questioned sample for future examination by other experts. Detailed guidelines for the examination of fiber evidence have been compiled by the Scientific Working Group on Material Analysis.<sup>11</sup> A brief overview of the fiber examination process follows.

Initial identification of fibers is carried out using microscopic techniques. Low magnification, compound microscopic examination, and polarized light microscopy will reveal morphology and optical characteristics of the examined fibers. These procedures are nondestructive and are

preferred for preliminary examination, identification, and comparison of the fibers. Classification as natural or synthetic fibers is usually easily accomplished through microscopic analysis. Physical characteristics of manufactured fibers, such as the shape, color, diameter variation, inclusions, and surface characteristics, are readily compared by this process. Many fibers that appear similar to each other without magnification may be distinguished by these methods. In fact, the SWG guidelines state that an appropriate microscopic examination provides the most discriminating method of determining if fibers are consistent with coming from the same origin.

For a more conclusive comparison, fiber analysis should include at least two analytical techniques for classification, physical characteristics, and color. To determine those properties, the criminalist commonly employs several instrumental techniques including: visible spectroscopy, to obtain an objective evaluation and comparison of color; pyrolysis gas chromatography, to identify the generic class or subclass of the fiber; and infrared spectroscopy, to identify synthetic fibers.

The value of a fiber comparison is related to the occurrence of that fiber in the environment, the amount of fiber present, and the location of the fiber on the object. Some fibers, such as white cotton, are so common as to make the presence of single white cotton fibers or their comparison meaningless. Others, especially uniquely colored or shaped synthetic fibers or fibers in large quantity, may have greater potential significance.

**Paint** Coatings and paints are often encountered in motor vehicle accidents and burglary investigations, but may be useful information in other case investigations where there can be primary or secondary transfer of paint fragments. Paints are complex mixtures of pigments, binders, plasticizers, carriers, and other components. Some of these components are organic compounds, typically analyzed by FTIR and pyrolysis GC. Other components are inorganic substances suitable for SEM/EDX characterization. Often the paint fragments that are found as trace material contain multiple layers. Microscopic examination can reveal the layer color sequence and texture. Each layer can then be analyzed separately, providing a complex profile of the materials in that fragment. This "profile" can be compared to those of standard paint chips from a known source to determine similarity. The significance of a positive comparison depends on the number of layers present, the nature of the paint in each layer, and the occurrence of that paint in the environment.<sup>12</sup>

### Mineralogical Evidence

Soil and other mineral evidence is often overlooked during the collection of physical evidence. Soils can be separated into their organic and inorganic components, as well as the natural and man-made materials present in the sample. Using a petrographic microscope, the criminalist can determine the mineral and elemental composition of soils. Extracts of samples may contain trace amounts of ions and organic chemicals that add to the individual character of a

particular sample. Instrumental analysis of these extracts may demonstrate the presence of toxic chemicals in cases of environmental contamination. In addition, if several layers of soil are present, the layer structure of the deposited soil combined with analysis of biological materials present, such as plants, grass, pollens, animal hairs, and insect parts, may also provide useful information concerning the possible origin of the adhering materials. Mineralogical evidence usually has greater value when it involves a comparison to case samples of known origin.

### Construction Materials

Transfer evidence related to construction, including wood fragments, plaster, metal shavings, cement, asphalt, etc., can be analyzed and compared to standard materials. The type of analysis conducted will depend on the chemical nature of the construction material and the size of the sample. Even small wood chips and shavings may provide valuable clues to associate a victim with a crime scene. Differences between treated, preserved, or prepared and natural woods can be easily determined. The species of origin of a wood sample usually can be determined by wood experts, thus tracing the wood samples to their origin. Comparison between known and questioned wood materials collected in a case may provide critical linkage in the investigation.

### Associative Evidence

Physical evidence is often used to associate the victim or the suspect with the crime scene, an object, or each other. This linkage among various aspects of a crime is often critical and required to provide circumstantial evidence during trial. The actual nature of the evidence in this class will vary, but its primary use is for the purpose of associating various elements or persons. Some types of associative evidence are used to link an object to a specific individual. Paramount among those are vehicles, clothing, shoes, gloves, and tools. Associative evidence used for personal identification includes fingerprints, palm prints, bite marks, tattoos, x-rays, videotapes, and photographs. These associations have been used successfully for many years in investigations and as evidence in courts of law. Of equal importance is the *exclusion* of a person or object by the failure to make an association. Other materials, such as tool marks and firearms evidence, are based on a detailed examination of the individual markings produced when these objects are used. These striae cannot be used to link evidence directly to a specific person, but can provide important corroborating or exculpatory evidence of association or disassociation with two objects.

Valuable associative evidence can be obtained by appropriate use of national and local databases that are now available (Table 68-2). For example, after instrumental analysis is completed on a questioned vehicle paint sample, the national paint database can be searched for identification of the make and model of the automobile. This search can potentially provide key investigative information not available by other means. With the collection of samples from convicted felons, physiological evidence from a no-suspect

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Vehicle	Model, make, shape, logo, sign, damage	VICAP MVD request
	Paint, color, license plate	Garage Random check
Weapon	Size, shape, color	IBIS/NIBIN
	Bullet	Data check
	Cartridge case	VICAP
Clothing	Tool mark	
	Hat	Photographs
	Shoes	Videotape
Objects	Other clothes	Fiber database VICAP
	Mechanism	Manufacturer data
	Tools	UPC labels
Persons	Containers	
	Physical description	Sketch
	ID cards, birthmarks, tattoos, scars	Tattoo records Mug shots
	DNA profile	DNA database

**Table 68-2** Associative evidence: sources and information

case can be analyzed and the STR profile searched against the regional or national database. The successful association of individuals with blood and body fluid samples in cases that otherwise could not have been solved is now a common occurrence. DNA databases have been so successful that many states have greatly expanded the class of persons from whom samples are taken. Similar searches of the NIBIN cartridge case database have resulted in the association of previously unrelated crimes involving handguns.

## CHALLENGES TO CRIMINALISTICS EVIDENCE

Since the Supreme Court decision in *Daubert v. Merrell Dow Pharmaceuticals*,<sup>13</sup> criminalistics has entered a new era. Under the *Frye*<sup>14</sup> standard of general acceptance within the scientific community, criminalists were confident that, if consensus techniques were employed and proficiency tests acceptable, the result obtained was reliable. With long-standing disciplines such as fingerprints, hands-on experience produced a confidence in the absolute individualizations that were made. Initially, only DNA analyses were scrutinized at every stage of the testing process—from validation, to analysis, to quality control. The factors laid out in *Daubert* made it clear to the forensic community that consensus without well-documented validation would not be sufficient for the future. Judges took their role as gatekeepers to bar bad science very seriously.<sup>15</sup>

While some states still retain a version of the *Frye* standard, many have adopted *Daubert*. Some of those courts have held that certain techniques are so well founded in the forensic community that they do not require a *Daubert*-type hearing. However, numerous questions concerning the validation, quality control, peer review, and other factors are still appropriate. Answers to those fundamental questions must be satisfactory or they may still raise serious issues for

the jury concerning the reliability of the specific test application in a case.

Clear efforts are being made within the criminalistics community to establish more specific national standards for analysis and quality control guidelines, as evidenced by the creation of numerous scientific working groups and national certification oversight boards. These protocols reflect an awareness of the need for objective, reproducible results obtained within a quality system that can stand up to the rigors of the *Daubert*-type inquiry. Some subjectivity will always be part of the criminalistics process, however. It is the nature of criminalistics itself that scientific comparisons based on the evaluation of objective characteristics are always some part of the analysis. The other aspects of forensic evidence involved in interpretation and reconstruction are based on experience, logic, and objective evaluation.

## Endnotes

1. For example, the FBI has established a policy that a DNA profile frequency of occurrence of less than 1 in 260 billion would result in a reported individual source for a biological sample.
2. Time of death estimation based on insect species development and persistence has been accepted in numerous courts. For a general reference, see K.G.V. Smith, *A Manual of Forensic Entomology* (Trustees of the British Museum, 1986) or J. Byrd & J.L. Castner, eds., *Forensic Entomology: The Utility of Arthropods in Legal Investigation* (1990).
3. See *The State of California v. Orenthal James Simpson*, Case BA097211(1995). See also [www.courtstv.com/casefiles/simpson/new\\_docs/lee\\_testimony.html](http://www.courtstv.com/casefiles/simpson/new_docs/lee_testimony.html). In that case, questions concerning the identification of additional bloody shoeprints at the scene were raised by the defense. Prosecution experts initially contended that the patterns pointed out by the defense expert were, in fact, indentations in the walkway material and not related to the murder of Nicole Brown. The defense was able to show that the parallel-line type of imprints were, in fact, left by a bloody sole of a size 10 shoe.
4. General protein stains, such as amido black, are used successfully at crime scenes and in the laboratory. Also used is a bloody print enhancement reagent, based on the chemical presumptive test reagent TMB mixed with a plasticizer.
5. Edmond Locard, an early twentieth-century criminalist, postulated that, when objects, persons, or surfaces come in contact with each other, there is a mutual exchange of materials. This transfer may result in identifiable trace materials that can be used to link the objects, persons, or surfaces to each other.
6. See *Bogan v. Arizona* (1993), where a woman's body was dumped in the Arizona desert under a *Palo verde* tree. DNA from seed pods found in the suspect's trunk were matched to the tree under which the victim was found. Also reported in 260 *Science* (May 14, 1993).
7. While there is no overall agreement on the exact number of hairs necessary, all scientists agree that representative hairs should be removed from all areas of the region of the body being sampled, for example, 25 hairs each taken from the front, back, two sides, and top of the head. Some trace experts suggest examining these hundred hairs and then choosing a representative sample for permanent mounting and comparison to the questioned hairs.
8. Several of these cases have been reported from Oklahoma, where the laboratory examiner gave an opinion that hair evidence showed the accused was physically present at the scene based on her hair comparison results. See *McCarty v. State*, 765 P. 2d 1215 (Okla. Crim. 1988).

9. For a study of mitochondrial DNA typing of hairs previously associated with an individual, see Houck et al., *Correlation of Microscopic and Mitochondrial DNA Hair Comparisons*, 47(5) J. Forensic Sci., 964–67 (2002).
10. R.A. Wickenheuser, *Trace DNA: A Review, Discussion of Theory, and Application of the Transfer of Trace Quantities of DNA Through Skin Contact*, 47(3) J. Forensic Sci., 442–500 (2002).
11. *Forensic Fiber Examination Guidelines*, 1(1) Forensic Science Communications (Apr. 1999).
12. For detailed procedures for the analysis of paints, see the SWGMAT Paint Subgroup guidelines in Forensic Science Communications.
13. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993).
14. *Frye v. United States*, 293 F. 1013 (1923).
15. *United States v. Plaza et al.*, C.R. 98-362-10,11,12 (Jan. 7, 2002 and Mar. 12, 2002).

