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Crime Scene Investigation

Philosophy, Practice, and Science

Part Two

Professor Robert C. Shaler
Pennsylvania State University

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Course Syllabus

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Photo courtesy of Robert C. Shaler

About Your Professor

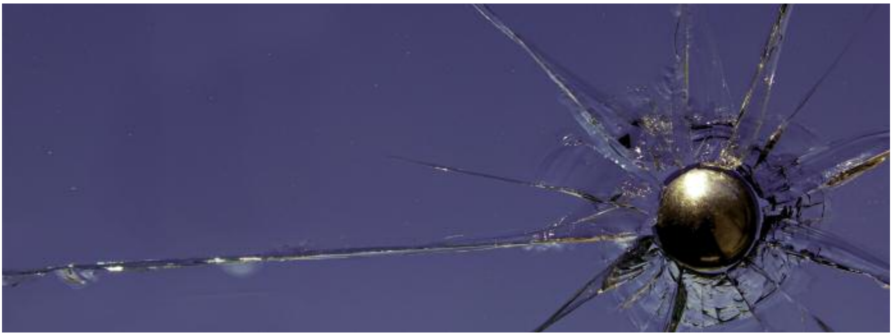
Robert C. Shaler

Robert C. Shaler, now retired, served as professor of biochemistry and molecular biology and director of the Forensic Science Program at Pennsylvania State University. He was the director of the Forensic Biology Department of the Office of the Chief Medical Examiner (OCME) of New York City from 1990 until his retirement in 2005.

As director, Shaler was responsible for the scientific and administrative operation of the Department of Forensic Biology in New York. He conceived the strategy for the DNA testing of family and World Trade Center (WTC) disaster samples for the identification of WTC victims. Shaler managed the WTC DNA victim identification effort, which included the OCME Department of Forensic Biology, seven contract DNA testing laboratories, one public forensic laboratory, and three software vendors. He also established a crime scene reconstruction unit operating from within the medical examiner's office. The unit responded to homicide crime scenes as secondary responders called by the district attorney, the New York Police Department (NYPD), and the medical examiner. The unit, now called FARU (Forensic Analysis and Reconstruction Unit), still operates. Shaler was a member of the National Research Council (NRC) that authored the 2009 report "Strengthening Forensic Science in the United States—A Path Forward." He was also on the NRC committee that authored the 2011 report "Review of the Scientific Approaches Used During the FBI's Investigation of the 2001 Anthrax Letters."

Professor Shaler's areas of expertise include bloodstain analysis, crime scene investigation and reconstruction, forensic DNA analysis, and forensic biology.

In part one of *Crime Scene Investigation: Philosophy, Practice, and Science*, Professor Robert C. Shaler leads a comprehensive study of the fundamentals of this intriguing, and always topical, science. Shaler imparts a clear understanding of crime scene investigation, from archiving the scene to the presentation of evidence in court proceedings. Covering everything from fingermarks and bloodstains to 3-D imaging and microbial forensics, the course is an essential guide for anyone intrigued by this riveting subject. Part one lays the groundwork for the topics covered in part two and together they comprise an excellent course of study for new students or seasoned investigators.



Introduction

Every touch leaves a trace. Such is the basis of the Locard exchange principle, which, as discussed in part one of this lecture series, forms the paradigm for crime scene investigators. An essential ingredient in forensic investigations, this transfer of evidence can be detected, catalogued, and produced for court proceedings, thereby making it a key part of the judicial system.

Part one of this series laid out the basics of crime scene investigation, including the fundamentals of scene management, the principles of evidence, searching scenes, forensic photography, and fingerprinting. In part two, Professor Robert C. Shaler provides further insight into a field that demands experience, logic, creative thinking, and the correct application of the scientific method. The following lectures delve even deeper into the crime scene by focusing on impression evidence, vehicle scenes, bloodstain pattern analysis, the importance of insects at crime scenes, and, finally, a vital and topical point of concern, mass fatality events and bioweapons.

Lecture 1

Pattern Evidence, Fingerprints: On-Scene Considerations, Part One

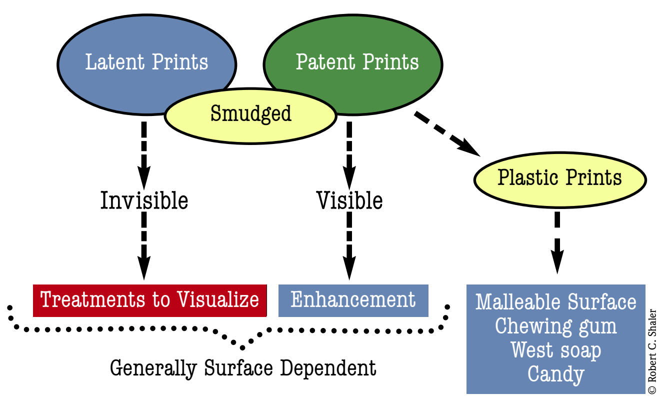
The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 10, "Fingerprints: On-Scene Considerations."

Finding probative pattern evidence is a critical component of any successful crime scene investigation. Fingerprints as a class of pattern or impression evidence can identify someone to the exclusion of everyone else. What techniques are employed and how do investigators decide which to use and when?

Fingerprints occur in three forms: latent (invisible), patent (visible), and impression or plastic, a subcategory of patent prints because the ridge detail is visible after being impressed into a malleable material. Others categorize fingerprints as positive, negative, or indented.[1] Once thought to be useless and without probative value, smudged prints constitute a subcategory of latent and patent prints. They have little or no discernable friction ridge detail useful for comparative purposes. This will change as science discovers better and more sophisticated tools to analyze them through DNA analysis.

In very broad strokes, Figure 1.1 illustrates the types of fingerprints found at scenes of crimes and generally what must be done in order to develop them. This can involve physical techniques as simple as powder dusting or complex chemical treatment such as Superglue fuming. Or, it might require using a special light source that causes the fingerprint residue to fluorescence; an example is an Argon or Nd:YAG laser[2] or an alternate light source (ALS).

Figure 1.1: Fingerprint Types Found at Crime Scenes



Archiving and preserving a patent print may require nothing more than photography followed by lifting. On the other hand, a partial print might have patent and latent parts, which might dictate a well-thought-out strategy for enhancing both. If the evidence is transportable, techniques are available in the laboratory where the conditions are controlled better. If the print is plastic, that is, impressed into a soft surface, the scene scientist/investigator might cast it using a silicone-based material, a cast that can be enhanced in the laboratory. The foregoing discussion was purposely broad in order to emphasize that the print types that populate scenes can unleash a cascade of developmental choices, many of which can be confusing to a student or a novice investigator.

Career crime scene investigators have routines for developing fingerprints at scenes. One investigator has written that photography of patent and plastic prints is sufficient to capture the detail necessary to make comparisons.

> Of the three types of fingerprints, visible fingerprints can be photographed directly, and impression fingerprints can usually be photographed under special lighting conditions. It is only the invisible latent fingerprints that are difficult to photograph. They must first be made visible.[3]

Following that investigator's advice could lead to a failure to adequately capture potentially probative evidence. Patent prints are unique. They exist because of contamination from an exogenous source, such as blood, oils, cosmetics, and so on. Employing photography as the sole means of archiving these prints captures only that which is visible, missing that which is invisible.

Understanding how to develop fingerprints at the scene or in the laboratory requires an understanding not of how fingerprints develop during gestation but the chemistry of the fingerprint residue left at the scene. This requires an understanding of the origin of the fingerprint residue.

The Glandular Origin of Fingerprints

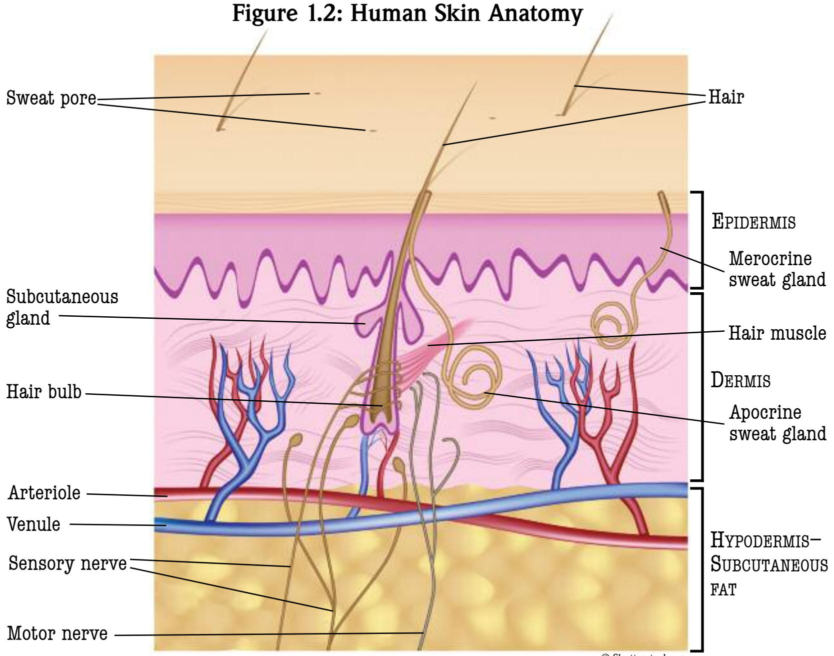
Fingerprints at scenes of crimes result from someone touching a surface and leaving a residue, which is an emulsion comprising molecular substances from the secretions from sweat glands in the skin and exogenous contaminants: blood, oils, cosmetics, and so on. This seems rather simple because the components of glandular secretions are known and their chemistries understood. The fact is that this is a complicated mixture. First, the glands necessary to form the fingerprint residue are not all present on the friction ridge skin of the hands or feet, and the fingerprint residue at the scene can also be contaminated by sources that are not manufactured by the human body.

Generally, fingerprint residue can be divided into water soluble and insoluble substances. The glands secreting directly onto the friction ridge skin are sweat glands or sudiferous glands, of which there are two types: apocrine and merocrine (relating to or produced by glands that make secretions without cell damage or disintegration). Both have myoepithelial cells that contract, that is, squeeze, leaving discharges on the skin.

Sweat glands play specific roles in the body. The apocrine glands are scent glands and respond to emotional stress. They begin functioning at puberty and produce moisture during emotional experiences such as when someone is upset, frightened, or experiences pain. They are also active when a person is sexually stimulated. In adults, the apocrine glands are most numerous in the armpits (axillae), groin associated with hair follicles, and the regions around the nipples (areoles). Historically, these secretions have not been forensically important, especially with respect to locating latent fingerprints at the crime scene. The secretions are viscous and cloudy and under bacterial action can produce a noticeable odor. It is unfortunate that these secretions have not found a routine forensic utility because their location suggests a potential forensic role in sexual-assault investigations.

The primary merocrine gland on the friction ridge skin are the eccrine sweat glands. They are present throughout the body and are more numerous than apocrine glands, especially on the palms and soles—approximately 3,000 glands per square inch. Their densities range from 60 per cm^2 on the thigh to 350 per cm^2 on the forehead.[4] They are coiled structures lying deep within the second dermal layer of the skin, the dermis. The coil runs up through the upper dermal layer, the epidermis, and empties onto the skin surface on the epidermal ridges of the friction ridge skin. They are not

Figure 1.2: Human Skin Anatomy



associated with hair follicles. The gland is lined with sweat-producing cells that respond to elevated body temperature due to environmental heat or physical exercise. They produce profuse sweating on hot days or when a person is physically active. This is the gland that produces moisture on the palms and soles when someone is emotionally stressed. These secretions include several substances that have forensic value with respect to fingerprint development.

The sebaceous glands also contribute to the fingerprint residue. These are known as holocrine glands (secretions derived from the substance of the gland itself). The secretions come from oily substances from broken cells, sebaceous cells, which produce globules of a fatty material that accumulate inside the cell. Eventually, the oils accumulate to the point where the cell swells and bursts, resulting in a mixture of fatty material and cellular debris on the skin called "sebum." Sebum is found on all areas of the skin except the friction ridge skin and is most prominent on the forehead and areas where there is hair.

The secretions of the eccrine, holocrine, and sebaceous glands all contribute to the fingerprint residue left at the crime scene. Importantly, eccrine glands are found all over the body, including friction ridge skin, but sebaceous glands are not found on the friction ridge skin. The apocrine glands do not secrete as much material as the other two, and while they are located on all areas of the body, they are most prominently associated with hair follicles in the groin. Importantly, sebaceous and apocrine glands are associated with hair follicles but eccrine glands are not.

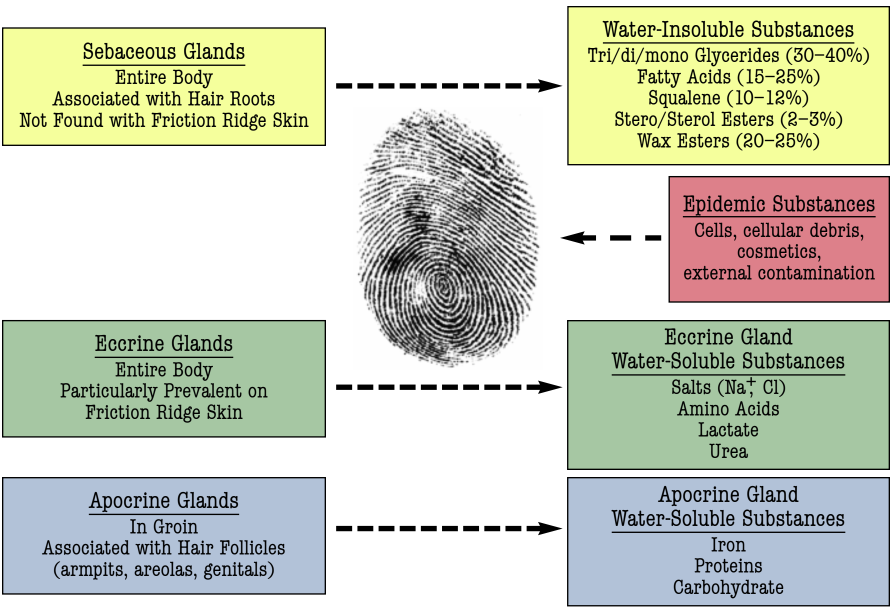
Sebaceous secretions become a component of fingerprint residue when an individual touches regions of the skin where these glands are plentiful, for example, head, cheeks, and forehead. The eccrine glands are particularly plentiful on the friction ridge skin—hands, palms, and soles of the feet. By definition they will always contribute to the fingerprint residue. From a practical perspective, apocrine secretions contribute to the print residue only if someone touches the groin area.

For the crime scene investigator, the discussion above might seem academic and not particularly relevant to how one successfully locates fingerprints at the crime scene. But thinking like this is a mistake. In order to properly and successfully develop fingerprints at the scene or in the laboratory, the scene investigator must understand the chemistry of the fingerprint residue as well as how and why it interacts or reacts with various surfaces and its immediate environment.

As mentioned, fingerprint residue contains two broad categories of chemicals: those that are soluble in water and those that are not. The water-soluble substances arise primarily from eccrine glands found on the friction ridge skin. The water-insoluble substances come primarily from the sebaceous glands found on skin populated by hair follicles. The subject of the chemical components of fingerprints has been discussed in-depth by others.[5–7]

The schematic in Figure 1.3 illustrates the origin of the endogenous fingerprint residue and why it contains a mixture of each of the body's major secretory glands. The contributory substances represent the primary classes of substances of interest. Investigators should never lose sight of the fact that the diagram is a snapshot as a way to represent the complex nature of the fingerprint residue mixture present. In fact, each gland secretes many more substances.

Figure 1.3: Origin of Fingerprint Residue



Each gland can contribute to the overall chemistry, but the relative contribution of each depends on the habits, stress level, and physical exertion of the person leaving the print. If someone continually runs fingers through his scalp or habitually touches his face or forehead, his prints will likely have an abundance of sebaceous secretions. If he is fastidious and is continually washing, his prints might be cleaner; that is, they will likely have a relatively smaller contribution of sebaceous oils. If during a sexual assault, the assailant touches his or the victim's groin region and then subsequently touches something at the scene, say, a knife, the residue on the handle of the knife should have an elevated level of apocrine secretions relative to those from eccrine and sebaceous glands.

From an academic perspective, it should be possible to determine the relative proportions each gland contributes to the fingerprint by measuring the concentration of sebaceous-, eccrine-, and apocrine-specific substances present. For example, delta 6 fatty acids have a sebaceous origin and lactate is one of the prominent constituents of eccrine secretions.

Determining their ratio might provide information with respect to the relative contribution of each gland to the fingerprint. From an investigative perspective with respect to developing useable prints on-scene, knowing the relative glandular contribution to fingerprint residue might allow a more precise development at the scene. As of this writing, this technology is not available. More likely, such testing would occur in the latent print laboratory. At the scene, a priori it is not yet possible to accurately ascertain the relative gland contributions to the print residue present.

One group of researchers believes that fingerprints comprise only 5 percent sebaceous secretions, which leads them to conclude that eccrine secretions make up the bulk of the print residue. They speculate that eccrine secretions—lactate—are responsible for the success of one type of fingerprint development: using the Superglue-fuming reaction using the heat/humidity method and that aged and otherwise compromised latent fingerprints can be recovered using acetic acid or ammonia vapors.[8]

Finding Fingerprints at Scenes: General Considerations

Latent and patent fingerprints are found anywhere and everywhere. The problem is locating and developing them. Although transportable scene evidence can be taken to the latent print laboratory, some need to be developed at the scene. This creates the problem of finding the fingerprints having probative value.

Figure 1.4 offers suggestions with respect to where to find fingerprints at scenes. Certainly, it is a waste of time to memorize the list because the most important items are the last two points in the right-hand list: use your imagination so that you become the burglar (perpetrator). This is when a search for probative prints pays off. Searching is an intellectual exercise. The thought process might go something like, "*What would I touch if I were the scumbag who did this?*"

Figure 1.4: Finding Fingerprints at the Scene

- Point of entry
  - –Broken entry
    - Prints (including shoe prints)
      - –Lock
      - –Immediate surroundings
  - –Window
    - Pieces of broken glass
      - –May have blood
      - –May have been tossed aside to conceal entry
    - Windowsill window jamb
    - Tables used to support weight
    - Floor where burglar walked/stood
- Trace the path
  - –Where eaten/drink
    - Glass & china are good targets for prints
    - Can discard gloves
  - –Light switches
  - –Circuit breakers/fuses/lightbulbs loosened
  - –Areas where gloves were a hindrance
  - –Toilet flush lever
- Tools left behind
  - –Flashlight batteries
  - –Latex gloves
- General surfaces
- Fabrics
- Use your imagination
- BE THE BURGLAR

FOR GREATER UNDERSTANDING

Questions

1. Name three categories of fingerprints found at crime scenes.
2. Sweat glands produce the components of fingerprint residue left behind at scenes when an assailant touches a surface. Describe the glandular origin of each of the following components: amino acids, fatty acids, and salt.
3. The gland that opens onto the friction ridges on the palms, fingers, and soles of the feet originates from which of the following sweat glands?

   a. Sebaceous glands
   b. Apocrine glands
   c. Holocrine glands
   d. Eccrine glands
   e. None of the above

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Champod, Christophe, Chris J. Lennard, Pierre Margot, and Milutin Stoilovic. *Fingerprints and Other Ridge Skin Impressions*. Boca Raton, FL: CRC Press, 2004.

Lee, Henry C., and R.E. Gaensslen. *Advances in Fingerprint Technology*. 2nd ed. Boca Raton, FL: CRC Press, 2001.

Montagna, William, ed. *The Structure and Function of Skin*. 3rd ed. Maryland Heights, MO: Academic Press, 1974.

Lecture 1 Notes

1. Champod, Christophe, Chris J. Lennard, Pierre Margot, and Milutin Stoilovic. *Fingerprints and Other Ridge Skin Impressions*. Boca Raton, FL: CRC Press, 2004. P. 105.
2. Home Office Scientific Development Branch. "Operational Performance of Nd:YAG Green (532 nm) Laser." *HOSDB Fingerprint Development and Imaging Newsletter*. Publication no. 34/06.
3. Brown, Eric W. "The Cyanoacrylate Fuming Method." Available at http://www.ccs.neu.edu/home/feneric/cyanoacrylate.html (accessed 7/12/11).
4. Quinton, Paul M. "Sweating and Its Disorders." *Annual Review of Medicine*. Palo Alto, CA: Annual Reviews. 34: 429–52, 1983.
5. Montagna, William, ed. *The Structure and Function of Skin*. 3rd ed. Maryland Heights, MO: Academic Press, 1974.
6. Lee, Henry C., and R.E. Gaensslen. *Advances in Fingerprint Technology*. 2nd ed. Boca Raton, FL: CRC Press, 2001. Pp. 63–104.
7. Champod, Christophe, Chris J. Lennard, Pierre Margot, and Milutin Stoilovic. Pp. 105–115.
8. Wargacki, Stephen P., Linda A. Lewis, and Mark D. Dadmun. "Enhancing the Quality of Aged Latent Fingerprints Developed by Superglue Fuming: Loss and Replenishment of Initiator." *Journal of Forensic Science*. 53(5): 1138–44, 2008.

Lecture 2

Pattern Evidence, Fingerprints: On-Scene Considerations, Part Two

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 10, "Fingerprints: On-Scene Considerations."

Developing fingerprints at crime scenes requires a reasoned approach and knowledge of the techniques available and the surfaces on which fingerprints are found.

Scene detectives have used dusting powders to develop fingerprints since the nineteenth century, a trend that continues unabated. Powders are the most ubiquitous technique for developing nonporous and selected porous surfaces. There is a huge list of dusting powders available from commercial suppliers, most designed to solve surface-related problems: for instance, texture, porosity, color, and cleanliness. Many factors influence the success of powder dusting, some of which are not under the control of the investigator: the nature and condition of the surface and the clarity of the ridge detail and its age, which affect how well a powder adheres to the print emulsion.

Variously textured surfaces commonly encountered at scenes present challenges different from smooth surfaces because powder particles can be trapped in the crevices. There is the issue of which powder to use: metallic powders, black, gray (dual), fluorescent, magnetic, bichromatic, or powder formulations. Generally, the following apply.

- Black or jet-black magnetic powders should be used on textured surfaces.
- Black or jet-black magnetic powders should be used on u-PVC surfaces.

Importantly, all surfaces may respond better to chemical treatment, which should be considered before embarking on a fruitless strategy.

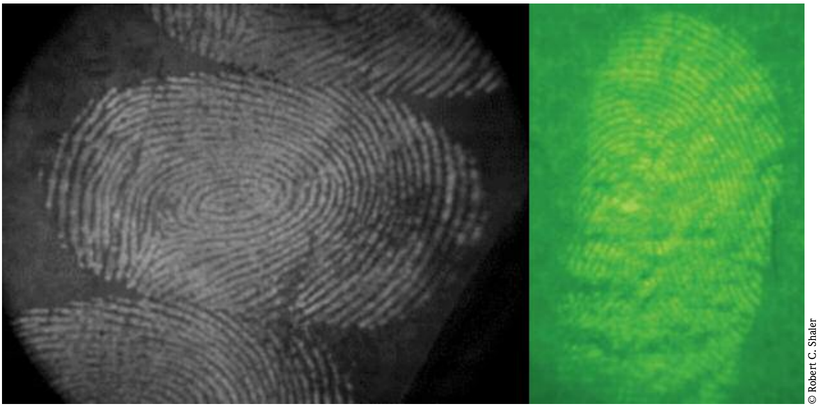
Fingerprints and DNA

Lifting fingerprints using traditional lifting methods does not quantitatively capture fingerprint DNA. To ensure collecting all of the DNA, the area of the lifted fingerprint should be swabbed after lifting using a swab designed for DNA. There has also been the suggestion that fingerprint brushes can contaminate DNA from one fingerprint to another. While the chances of this are extremely slim, using magnetic powder dusting reduces the possibility significantly.

Superglue (Cyanoacrylate or CA) Fuming

A widely employed technique at scenes as well as in the latent print laboratories takes advantage of the fact that Superglue fumes (cyanoacrylate monomer vapor) react with components in the fingerprint residue to form polycyanoacrylate polymer along the ridges. The result is an off-white residue that is nearly invisible on light surfaces and off-white on dark surfaces. Figure 2.1 is a photograph of a Superglue-developed fingerprint on a dark surface.

Figure 2.1: Superglue-Developed Fingerprint on a Dark Surface and Stained with Basic Yellow 40



These Superglue-developed fingerprints show high ridge definition. The print in the image at the right was dyed with Basic Yellow 40.

From a scene investigative and case perspective, Superglue fuming at the scene has advantages.

- The fuming process protects fingerprints, which reduces the risk of damage during transport to the laboratory.
- The polycyanoacrylate entombs the DNA present.
- On-scene fuming is appropriate for objects that cannot be transported to the laboratory.
- On-scene fuming is possible and recommended for objects that will be damaged during transport to the laboratory.
- On-scene fuming can be used to obtain on-scene investigatory information.

There are also disadvantages.

- On-scene fuming is typically done in an uncontrolled environment, which can be detrimental to quality of the developed print.
- Most on-scene CA fuming involves the heat and humidity fuming process, leaving the possibility of overdevelopment.

- Because of the ease of the technique, there is little consideration of an appropriate strategy for using on-scene Superglue-fuming development.

The chemical mechanism of the cyanoacrylate (Superglue) polymerization reaction is well understood. Investigators should know when and how to employ it based on how the environment or the surface might affect the quality of the developed fingerprint. The reaction can be easily demonstrated by dropping a drop of Superglue into a small amount of water, methanol, or ethanol. The result is a cloudy solution that quickly grows as the monomer polymerizes to form the white polycyanoacrylate polymer. Since the fingerprint residue is an emulsion in which water is present, there is the possibility that this is the initiating species. However, there are other possibilities: fatty acids, amino acids, and lactate. Most crime scene investigators believe that water vapor is necessary for Superglue polymerization. The water vapor used in the Superglue reaction probably keeps the aqueous phase of the emulsion saturated, but the water in the emulsion is more likely the species that creates an environment for other reactive species that initiate the reaction; that is, the Superglue reaction can occur in the absence of water vapor—vacuum Superglue fuming argues against water vapor (humidity) as the prime initiator.

There are two Superglue-fuming methods for vaporizing Superglue: heat and humidity (H&H) and vacuum and variations of these. However, because of the widespread belief that water vapor is required, most fuming in the laboratory and at the crime scene employs what is known as the heat and humidity method.

The fuming process is forgiving, and it is easy to delude oneself into thinking that, if results are obtained, it does not matter how the test was conducted. Such reasoning is certainly nonscientific. If a method is simple to employ and inexpensive to set up, it does not mean that the appropriate scientific procedures and controls should be ignored. The equipment and supplies required for CA fuming is simple: Superglue, an aluminum pan or foil, heat sources (a lightbulb, a coffee warmer, or a hot plate to volatilize the cyanoacrylate, and another hot plate to vaporize water). Place these in the fuming chamber (a fish tank with a lid) and you have a Superglue-fuming chamber. Commercially available fuming chambers and devices are also available.

Visualizing CA-Fumed Fingerprints

Regardless of the fuming technique, visualizing the fumed print requires a second process that typically includes either powder dusting or staining the fumed print with a fluorescent dye. Dusting a fumed print is no different than routine print dusting for any surface, except that the location of the print is known. Lifting is accomplished in the same way using tape and transferring the print to a fingerprint card. Because the CA-fumed print has a rigid structure, the print can be redusted and lifted numerous times. The choice of powder depends on the color of the surface on which the fumed print lies.

On-scene staining of fumed prints without thinking through the process can ruin the evidence if the surface absorbs the dye. When this happens, the background fluorescence will mask or reduce the contrast of the print's fluorescence.

Lifting Developed Prints

Powder Dusted Fingerprints

After developing and photographing prints, the next step is lifting. The process, like many on-scene manipulations, is deceptively easy, but there is skill involved. The most important skill is the thought process with respect to determining the best method for obtaining a successful lift. Obviously, prints are found on all surface types, and once developed, remain there. Thinking through how to best lift the print is critical for obtaining the most ridge detail possible. Surface texture is one consideration. This is illustrated in Figure 2.2.

Figure 2.2: Example of Texture on a Wall

At first glance, the area on a wall in a home where fingerprints are suspected ❶ appears to be smooth, but on closer inspection there is texture ❷.

The wall's texture is a series of hills and valleys that can affect the quality of the lift depending on the technique employed. Regardless of the situation, logic should control the approach strategy for developing fingerprints on textured surfaces.

On perfectly flat, smooth surfaces, tape lifting is the fastest and easiest method for lifting dusted prints; interestingly, tape lifting does not always lift the entire dusted print, leaving some of the print detail and DNA behind. Assume tape was used to lift prints from the wall in Figure 2.2. In Figure 2.3, the undulating green line represents the textured wall, the white dots are the fingerprint powder-dusted print ridges and the straight blue line is the lifting tape. If the print penetrates into the depth of the textured surface, the dusting powder will also extend into the recesses of the texture. The tape, however, is not flexible enough to get into the texture. The result can be a partially lifted print, which will have gaps in the friction ridge detail and can mean the inability to compare the print successfully.

Figure 2.3: Tape Lifting Fingerprints on Textured Surface

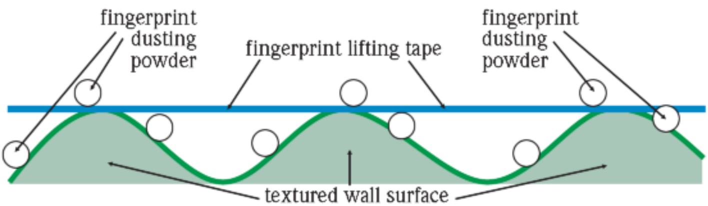


Figure 2.4: Bloody Fingerprint Developed on Textured Surface

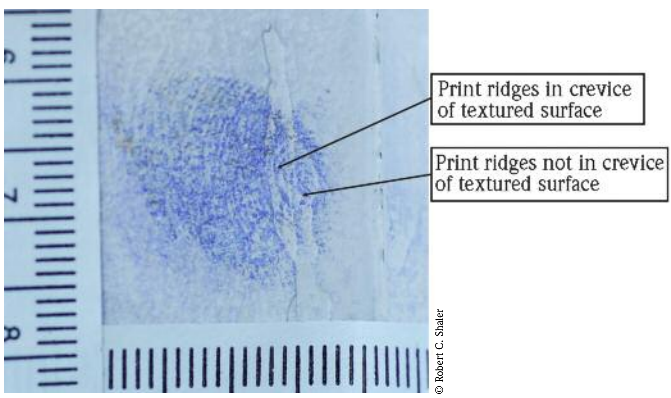


Figure 2.4 is an illustration of how fingerprint residue can penetrate into the crevices of a textured surface. The bloody fingerprint was enhanced with the protein stain Acid Violet 17.

Silicone casting materials such as Mikrosil™ can lift dusted prints on textured surfaces. The pliable silicone conforms to the texture of the surface and engulfs the dust-developed print. When hardened and removed, its adhesive forces (stickiness) entrap the dust on the print ridges and lift it intact.

Gelatin lifters (gellifters) are commercially available in the form of rubber or acetate backed flexible gelatin. With respect to malleability, gellifters fall between tape and silicone. These gelatin lifters have enough "give" and stickiness to capture ridge detail in the examples shown above, but not if the texture runs too deep. Gellifters are available in black, white, and clear, so if the choice is to use a gellifter, dusting powder color determines which to use.

Fingerprints on Adhesive Tapes

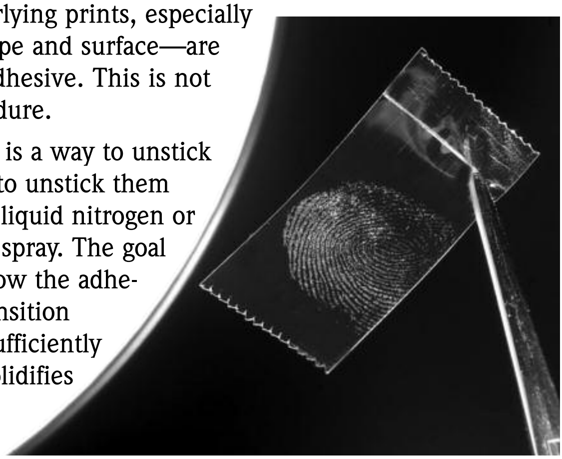
Anyone who has handled adhesive tapes knows that it is easy for fingers to stick to the sticky side of the tape. The result is a print impression transferred to the tape. Simultaneously a latent print might be deposited onto the smooth side of the tape. Even when criminals use latex gloves, handling adhesive tapes presents a problem because the stickiness makes handling the tape clumsy, and the result is often torn gloves or no attempt to use gloves at all. Finding fingerprints on adhesive tapes is a worthwhile endeavor. In fact, on-scene, it should be axiomatic that prints are present on both surfaces.

Using dusting powder on the sticky side of the tape is not an option because it will stick to the adhesive and mask the fingerprint. Other methods have been developed, however. The problem with developing prints on the sticky side of tapes concerns the chemistry of the adhesives. There are also physical issues concerning tape stuck to various surfaces, including itself. A rule of thumb is that adhesives should be collected, preserved, and taken to the laboratory for print development, especially if the tape is stuck to itself. However, there are instances when the tape is stuck to a surface that cannot be transferred to the laboratory, so unsticking the tape and developing the prints on-scene is necessary.

Removing Stuck Tape

Because the two surfaces of adhesive tapes have such different properties, a reliable strategy is needed for preserving the print evidence on both sides of the tape. An immediate problem is how to remove the tape from the surface on which it sticks without ruining the prints. Several methods have been proposed.

- Physical processes refer to physically removing the tape from the surface to which it sticks by pulling or teasing. The process is tedious and there is always the possibility of distorting the tape and thus altering the underlying prints, especially if the two surfaces—tape and surface—are tightly bound by the adhesive. This is not a recommended procedure.
- Cooling adhesive tapes is a way to unstick them from surfaces or to unstick them from themselves using liquid nitrogen or a microcircuit freezing spray. The goal is to cool the tapes below the adhesive's critical "glass transition temperature." When sufficiently cooled, the adhesive solidifies so that it can be *gently*



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and slowly pulled from the surface or from the sticky side of an adhering adhesive. Essentially the frozen adhesive "fractures" from the surface to which it is bound.[1] Using a freezer spray made for the electronics industry is tantamount to using liquid nitrogen. The temperature of the sprays are in the –65°F range, so it is important to wear appropriate personal protective equipment (PPE): gloves, face mask, and protective clothing.

- Hydrocarbon-based solvents have also been recommended for adhesives stuck to other adhesives (for example, UnDo™). The process is slow and tedious, and only tiny amounts of solvent should be used because too much will dissolve the adhesive and ruin prints.

Packaging and Protecting Adhesive Tapes

The three primary problems concerning packaging and protecting adhesive tapes are as follows:

1. Protecting prints on both sides of the tape during transit to the laboratory.
2. Protecting prints on the adhesive side while processing the smooth side.
3. Packaging the tape in order to prevent the inadvertent contamination or obliteration of the prints.

One method for protecting and storing the adhesive side is to cover the adhesive side with silicone release paper. The smooth paper is easily removed without disturbing the adhesive.

Tapes should be stored in a high-quality cardboard or plastic box, and measures should be taken to prevent the adhesive side of the tape from coming in contact with the box surfaces. The adhesive side should be placed down onto the silicone release paper. The protected tape is then transported to the storage box and fixed in place inside the box. More than one strand of adhesive tape can be fixed to the silicone release paper and put into the storage box. Each tape must be labeled properly.

Sticky-Side Fingerprint Developing

Several techniques are available for developing prints on the sticky side of tapes. But choosing the most appropriate requires knowing or being able to discern the chemistry of individual adhesives. Chemically, the adhesives of tapes differ, which is why powder suspensions and chemical-formulation development techniques work with one type of tape and not another. Tape adhesives are categorized as rubber-based or acrylic-based; masking tape represents a third category, which can have either type of adhesive, and its porosity creates additional issues concerning print development.

A spot test is available that can easily and quickly identify the correct method to use.[2]

Rubber-based Adhesives

Most adhesive tapes have rubber-based adhesives and while they come in different colors and sizes, they should be receptive to dye and powder suspension development methods and Superglue fuming followed by fluorescent dye staining. The color of the tape is also important. If the decision is to attempt to develop prints on-scene, powder suspensions are a common choice.

Two powder suspensions, black and white, are recommended for developing fingerprints on rubber-based adhesives. Two different formulations are available: carbon-based (available commercially) and iron oxide-based (prepared in-house) suspensions. Each has a specific adhesive with which it is recommended.

Acrylic-based Adhesives

Few tapes fall into this category but they are physically indistinguishable from rubber-based adhesives. The spot test is an important first step in deciding which technique to apply. Basic Violet 3 is a dye that stains the fatty components of sebaceous secretions but not acrylic-based adhesives. The result is an intense purple color of the print ridges.

Spot Testing Adhesives[3]

The following procedure can be used to differentiate rubber-based from acrylic-based adhesives on the sticky side of adhesive tapes.

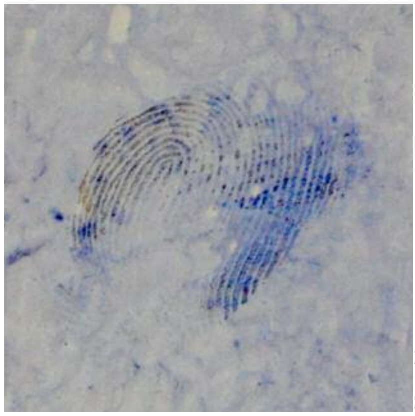
Procedure

- Apply a toothpick-sized but clear spot of black or white powder suspension to a section of the tape that is less likely to have been handled.
- Wash the spot and only that area of the tape with tap water until the excess powder is gone.
- If powder remains on the spot, the adhesive is *probably* acrylic-based and should be developed using an aqueous version of Basic Violet 3 (Gentian Violet).
- If the tape is visible after washing the test spot, it is probably a rubber-based adhesive and should be developed using powder suspensions.

Patent Prints

Patent prints can also have a latent component, which must be considered in the strategy to develop the entire print. An example of a partial bloody patent print enhanced with a protein stain is shown in Figure 2.5.

Figure 2.5 Commassie Blue-Stained Bloody Fingerprint



© Robert C. Shaler

Figure 2.5 shows a fingerprint enhanced by Commassie Brilliant Blue stain, which was originally developed for the textile industry but is commonly used for staining proteins in analytical biochemistry. Had the investigator who stained the print to enhance the blood first dusted the print, the nonbloody ridge detail might have also been developed.

Fingerprints and Heat: Fire Scenes

Arsonists and terrorists handle accelerants, explosives, and incendiary devices. At the scene, these are considered fire and explosion debris. Incendiary devices, such as Molotov cocktails, are examples on which fingerprints might be present. A perception that the fire and/or explosive environment or suppression efforts destroy conventional evidence such as fingerprints is apparently not true, although the literature on the persistence of fingerprints at arson scenes and on incendiary devices is scanty and often anecdotal.

Several studies suggest that fingerprints can withstand the temperatures measured at arson scenes. Harper's[4] and Shelef's[5] work and that of the British Home Office Scientific Development Branch (HOSDB) suggest that fingerprints can withstand temperatures of at least 300°C. In addition, the recovery of useful marks articles covered by heavy soot deposits might withstand temperatures up to 700°C or more.

© Avon, OH Fire Department

The remains of a Molotov cocktail made from a beer bottle bore two smudged prints that investigators were able to recover and later used to help convict an Ohio arsonist.

Locating Fingerprints at Arson Scenes

Finding probative fingerprints should be a priority of arson and explosive scene investigators. Knowing where to look is the problem because items of potential evidence at arson scenes may be soot covered. Investigators should attempt to gauge the hottest points at the scene and then confine collecting evidence in areas where temperatures did not rise above 300°C. In fact, it seems that temperatures above 200°C could destroy the organic components of the fingerprint residue, leaving inorganic salts, unless protected.

Another consideration is fire suppression. Water, per se, will not destroy the oils in fingerprint residue because they are insoluble. However, if the temperature of the fire was high enough to destroy the organic components of exposed residue, only inorganic salts will be left, which are water soluble. Generally, investigators should consider that fingerprints exposed to less than 300°C and items protected from direct exposure to heat and smoke are retrievable.[6]

FOR GREATER UNDERSTANDING

Questions

1. Powder dusting is a common technique for raising latent fingerprints at the crime scene. What is the best powder development method to use to raise prints on highly textured surfaces?
2. What are the advantages of Superglue fuming latent fingerprints at the crime scene?
3. What are the two general methods of Superglue fuming to develop latent fingerprints?
4. Assume you have Superglue-fumed prints on a light switch made of white plastic and, using oblique lighting, you can barely see fumed fingerprints. Give two general methods for better visualizing the developed Superglue-fumed fingerprint.

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Champod, Christophe, Chris J. Lennard, Pierre Margot, and Milutin Stoilovic. *Fingerprints and Other Ridge Skin Impressions*. Boca Raton, FL: CRC Press, 2004.

Lee, Henry C., and R.E. Gaensslen. *Advances in Fingerprint Technology*. 2nd ed. Boca Raton, FL: CRC Press, 2001.

Lecture 2 Notes

1. Home Office Scientific Development Branch. "Additional Fingerprint Development Techniques for Adhesive Tapes." *HOSDB Fingerprint and Imaging Newsletter*. Publication no. 23/06, March 2006.
2. Ibid.
3. Ibid.
4. Harper, William W. "Latent Fingerprints at High Temperatures." *Journal of Criminal Law Criminology Police Science*. 39: 580–83, 1938.
5. Shelef, Ran, Aharon Levy, Itzik Rhima, Shalom Tsaroom, and Rina Elkayam. "Development of Latent Fingerprints from Incendiary Bottles." *Journal of Forensic Identification*. 45(5): 557–69, 1996.
6. Bleay, Stephen M., Georgina Bradshaw, and Jennifer E. Moore. "Guidelines for Recovering Fingerprints from Arson Scenes." *HOSDB Fingerprint and Imaging Newsletter*. Publication no. 26/06, 2006.

Lecture 3

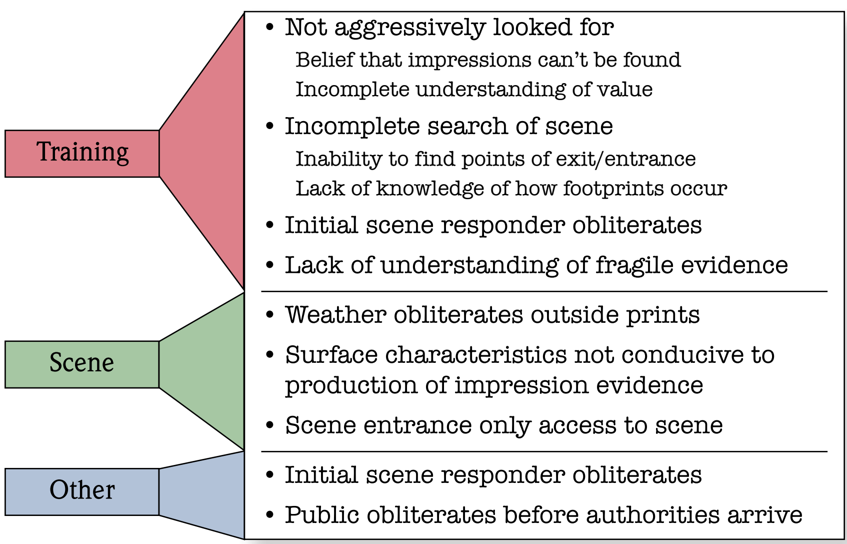
Impression Evidence: Footwear Impressions

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 11, "Pattern Evidence I: Footwear Impressions."

> ***Fingerprints are not the only important category of pattern or impression evidence. Footwear impressions have forensic value because, as associative evidence, they pinpoint that someone was at a particular scene.***

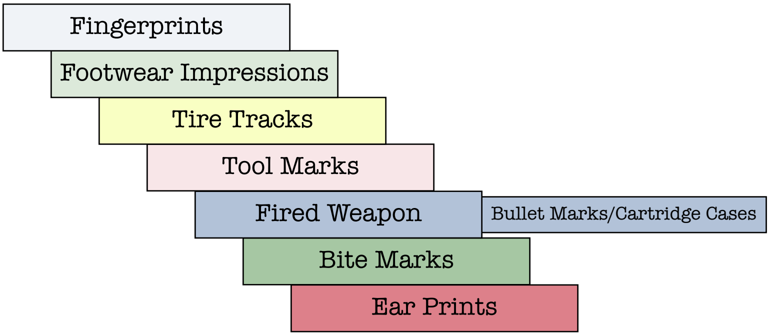
With the exception of fingerprints, impression or pattern evidence may be the most overlooked class of evidence in scene investigations.[1] The team leader is responsible for the investigation and must dictate the team's strategy, which includes when and where to search for or even consider that impression evidence is present. Figure 3.1 shows several reasons why impression evidence may be overlooked or ignored.

Figure 3.1: Why Impression Evidence Is Overlooked at Crime Scenes



Impression evidence comprises a large group, and it is almost axiomatic that at least one category is present at most scenes; the most prevalent are footwear and tire impressions and tool marks. Figure 3.2 illustrates other categories of common impression evidence.

Figure 3.2: Categories of Common Impression Evidence



Because of the diversity of impression evidence, we will focus on the most commonly occurring example, footwear impressions.

General Characteristics of Impression Evidence

Impression evidence occurs when a patterned object, such as the sole of a shoe, interacts with a surface leaving a patterned impression. These can be two dimensional (2D)—latent (invisible) or patent (visible)—or three dimensional (3D). An impression in dust is an example of the former, which is actually three dimensional because it has depth and surface topology, albeit shallow. Three dimensional impressions occur when an object impresses its pattern into a softer surface, such as when a car drives through muck, leaving a tire impression. Neil Armstrong's famous footwear impression on the moon is an example of a 3D impression.[2]

Figure 3.3: Neil Armstrong's Impression Print on the Moon

Public Domain/Courtesy of NASA

The Forensic Value of Footwear Impressions

Forensic value refers to the future use of an impression to help establish the truth of alleged facts either to inculpate (incriminate) or exculpate (clear from alleged fault or guilt) suspects. Typically, impression evidence falls into a category collectively called associative evidence. That is, it helps (supports) investigators, juries, and the judge determine whether someone may have been (or not) at a crime scene. Taken alone, it is typically not determinative of guilt. So, linking footwear evidence to an individual shoe can be critical for a prosecutor at trial to help determine the veracity of a suspect's statements. Such testimony at trial can be case defining.

A more immediate value comes from the scene, such that identifying unknown footwear impressions that are not the victim's has investigative importance with respect to telling investigators the minimum number of people who might have been involved in the crime. For example, if there were three unknown impressions, there could have been minimally three people involved in the crime. The operative phrase is "minimum number," as other perpetrators may not have left impressions or those at the scene may have come from people not involved in the crime.

Also, the path unknown footwear impressions weave through the scene can lead to other evidence, such as an egress point that can lead to fingerprints, weapons, or discarded burglary tools, etc. This is important on-the-spot investigative information.

Finding impression evidence requires a logical thought process, such as answering the questions below.

- What is the likelihood that probative impressions are at this scene?
- Where would they most likely occur?
- In what form would they be: wet or dry residue, plastic, latent, or visible?

Before embarking on a search for footwear impressions, the team should discuss where footwear impressions might be present. Just as all crimes have biological evidence, there is a reasonable chance that footwear or other impressions are present. This may seem intuitive, but apparently it is not.

Knowing that impression evidence should occur, locating, archiving, and collecting it can be elusive. And finding it requires an understanding of the surfaces on which impressions are found and whether a transfer of material from a perpetrator's shoe was likely. If a burglar enters a house through a window and steps onto a carpet, what is the probability that the dirt residue from the burglar's shoe will leave an impression? The outside environment defines the type of residue on the shoes, and subsequent steps will transfer that residue to the carpet. Whether the resulting impression has forensic value won't be known until it is found and evaluated. If the burglar's shoes are dry, an impression in dust is likely. However, if it had been raining and the burglar's feet are wet but not muddy a transfer is unlikely[3] and it's unlikely that the impression will be found.

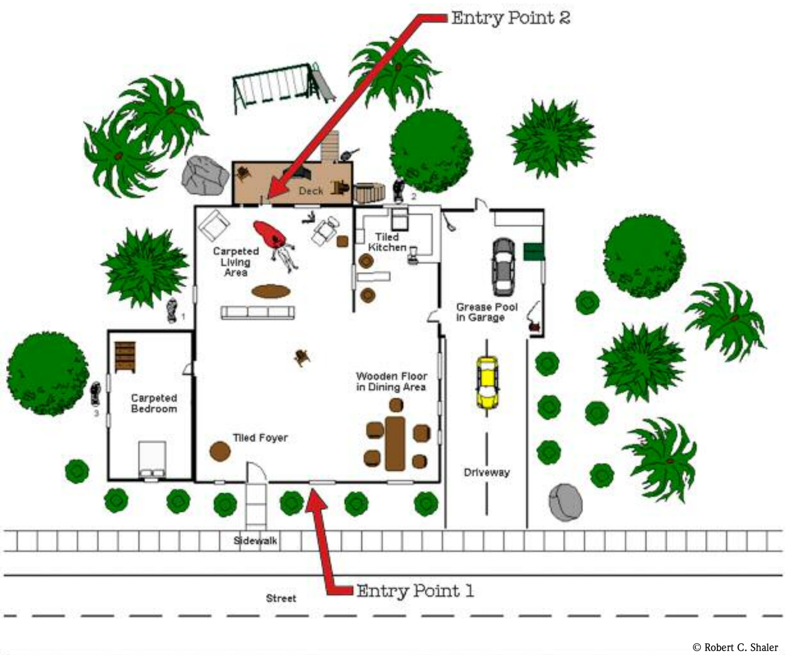
Not surprisingly, most footwear impressions are found on floors. Those having evidentiary value will likely be where the perpetrator entered or exited the premise, and tiled or hardwood foyer entries or linoleum tile are prime candidates. Common locations of footwear impressions are listed in Figure 3.4.

Figure 3.4: Common Locations of Footwear Impressions at Scenes

Where Are 2D Footprints at the Scene?
Most Footwear Impressions Found on Floor Surfaces
• Magazines, newspapers, and other paper materials • Tile floors • Dust prints on carpets • Shoeprints on doors (for example, kicked-in doors)
Requires Careful Inspection of the Scene
• Impression evidence is a category of fragile evidence • One of the first scene activities is to locate footwear and tire impressions

Consider the hypothetical burglary scene shown in Figure 3.5.

Figure 3.5: Hypothetical Burglary Scene



If the burglar had entered through Entry Point 2 at the top of the diagram, logic suggests that footwear impressions should be on the outside deck leading into the carpeted living area. Entering the house means stepping onto the carpet and dry residue prints should be visible.[4] If the prints are not readily apparent, logic dictates using a visual aid (for example, an oblique light using a flashlight or an alternate light source [ALS]) to visualize them. Then ascertain their probative value.

Common Footwear Transfers

Investigators should be aware of the most common types of footwear transfers. These can include the following:

- Dirt and/or dust
- Wet grass
- Grease, oil, wax, or furniture polish
- Blood or other fluids

Since dirt or dust on shoes typically comes from outside the crime scene, though not always, investigators should examine the soil and dust in the area of the crime (for example, is it muddy, sandy, or dusty). The fact is that impressions can be found on almost any surface: Kicked-in doors, vegetation, snow, and tiled or carpeted floors. Impressions in blood can be incriminating. Impressions from other liquids that spill during the commission of a crime can help trace a perpetrator's movements. The investigator who is "in synch" with the scene should be able to identify the location of the more difficult types of impression transfers.

Understanding the Composition of Dust and Soil

Dust, a general name for solid particles with diameters less than 500 micrometers, comes from the atmosphere: soil dust lifted up by wind, pollution, volcanic eruptions, animals, and people. Dust in the human environment originates from the local vicinity (homes and offices, for instance), contains human skin cells, bacteria, plant pollen, human and animal hairs, feathers, textile fibers, paper fibers, minerals from outdoor soil, and other materials. The amount and composition of house dust varies seasonally, and environmental factors such as the surroundings, exchange of outside air, age of the house, building materials and their condition, and the quantity of furniture and carpets, as well as their state of preservation, all play a role. It also depends upon the ventilation, heating/cooling systems, and habits of those living in the house. Generally, house dust consists of inorganic (minerals) and organic matter, their relative proportions varying considerably. The current paradigm for enhancing dust impressions at crime scenes, other than photography, is single dimensional, typically employing either a lifting technique or a chemical test to visualize the mineral content of the dust. The chemical approach is reasonable and predictable, but knowing the chemical composition of the dust/soil in the impression before blindly attempting chemistry to visualize the print would help. This means sampling a small portion of the dust using a metal ion test kit available from forensic supply houses.

Two-Dimensional (2D) Impression Evidence

The point is that 2D impression evidence is likely present at crime scenes simply because people are involved. This large class of evidence results from the transfer of something from the original impression to a receiving surface, and it can be almost anything: Coca-Cola,® motor oil, dust, mud, dust aqueous slurry that dries, lipstick, and other materials. Two-dimension impressions are found most anywhere and their number and variation are quite large. The following examples illustrate the point.

- Wet and dry (dust) residue prints on hard surfaces.
- Wet and dry residue prints on soft surfaces (carpeting, clothing, and furniture).
- Impressions made from nondust contaminants on the sole of the shoe (motor oil, beverages, and blood).
- Wet impressions on concrete, bricks, and paving stones).

There are two classes of latent or near latent 2D footwear prints at crime scenes: dry residue (dust) and wet residue prints (dust or mud). For the former, a dry shoe deposits dust onto an appropriate surface. For the latter, a wet shoe deposits a dust (or mud) slurry onto the surface, which dries. The impressions are visible when the dust or mud or another substance such as blood, or oil, transfers onto a surface with a contrasting color—a tan colored dust on a dark, tiled surface, for instance. If the print is latent or nearly latent, using a light source is a common way to "see" it. Various methods have been used to visualize impressions; the most common is to use a flashlight, an alternate light source, a mirror, ultraviolet light, or natural light. Once seen, the problem is identifying the kind of print, because this determines how to lift it and transfer it to a laboratory for analysis. The first step is to identify whether the impression is a dry (dust) or wet residue print.

Dry Residue Impressions

This is a simple matter of understanding how two methods work and knowing how to use them properly. The first step is to photograph it. Then lift it. Many investigators consider lifting as a reasonable first step because of an ingrained strategic paradigm of a proper lifting protocol that says if the print can be lifted using an electrostatic lifter, it must be a dry residue impression. Although not strictly true, the first approach should be to use an electrostatic lifter, which is an easy, nondestructive method. A second method is to use a gellifter, which is also easy and fast. The former uses an electrostatic charge imparted to the dust by an electrical current. Gellifters are a sticky gelatin material that are used to capture several types of impression evidence. Before blindly pulling out the electrostatic lifter, it is wise to consider whether the electrostatic lifter will be effective. This means ascertaining whether the amount of dust on the surrounding surface might mask the impression detail, evaluating the depth, texture, thickness, porosity of the surface, and humidity.

The electrostatic lifting process using commercially available equipment is straightforward, and homemade devices are simple to make; a stun gun can be used. An example of an electrostatic lift is shown in Figure 3.6.

Figure 3.6: Example of an Electrostatic Dust Print Lift from Linoleum Floor

© Robert C. Shaler

Electrostatically lifted prints are quite fragile. Anything that can discharge the film will destroy the print and physical contact with anything will obscure impression detail. Storage creates longevity problems. The lifted film has a residual charge that attracts excess dust, and it will gradually lose its charge over time.

Storing lifts in flat, high-quality cardboard boxes preserves them more effectively than other suggested methods. Even when stored in a high-quality cardboard, the electrostatic charge will eventually dissipate and result in the loss of the impression. Storage conditions are also important. High humidity increases the rate of residual charge degradation.[5]

The other technique for lifting impression dust prints is to transfer the impression to a sticky surface, such as a gellifter, a gelatin-based lifting material available in several forms. Gellifting dust from a surface is a different mechanism than the electrostatic process. Gellifters have a sticky (not a glue), porous surface. The gellifter is pressed onto the surface. Its porous surface penetrates the pores of the impression-held surface. When the gellifter is removed, the dust remains on the lifter because the adhesive characteristics of the gellifter overcome the forces holding the dust onto its original surface—adhesion forces. Lifting (binding) occurs when the gellifter (adhesive) and the dust (adherent) have similar solubility characteristics, which means strong adhesion bonds form when the two surfaces spontaneously “wet” each other. This is why gellifters can lift dry and wet residue impressions. Thus gellifters are not a reliable method for differentiating the two types of impressions. A recent study comparing electrostatic lifting with gellifting showed gellifters were superior for some surfaces, electrostatic for others, and, for some, there were no differences.[6]

Generally, the recommendation is to store gel lifts in the same way as electrostatic lifts: high-grade cardboard box without the acetate cover.

Wet Residue Impressions

Wet residue impressions occur when the liquid slurry on the sole of a wet or damp shoe transfers material to a receiving surface and then dries. The resulting dried impression is called a wet residue impression that is more or less “fixed” to the surface. Differentiating between dry and wet impressions pertains only to impressions in dust and/or mud. Impressions made with other materials, such as grease, oil, or blood, cannot be lifted with an electrostatic lifter and perhaps not with a gellifter.

Enhancing Wet Residue Impressions

These impressions can be visualized or enhanced in several ways. The following is a guide for investigators who ultimately have the responsibility for preserving impression evidence. Developing or enhancing wet residue impressions follows a specific path, the ultimate success of which requires an understanding of the science underlying the technique, its limitations, and the surface chemistry on which the impression lies. Before embarking on a development technique, scene scientists/investigators should weigh the pros and cons of on-scene enhancement carefully. Generally, several techniques are available that can help.

- Dusting with black magnetic powder followed by photography and lifting using a white gel lifter
- Painting with powder suspensions (for example, Wetwop™ or iron oxide in a dilute Photoflo™ solution)
- Iodine fuming followed by development with 7,8-benzophenone
- Superglue fuming followed by basic yellow 40 (or other fluorescent dye) staining
- Gellifting

Figure 3.7 is an example of a wet residue impression dusted with black magnetic powder and then lifted using a white gellifter.

Logic and experience should dictate which method to use. Footwear impressions in soft drinks such as Sprite® and Diet Coke® are an example. Most methods are not suitable for enhancing and lifting these impressions. Although several techniques are candidates, Sprite® impressions respond better to several enhancement methods than Diet Coke® (for example, magnetic powder, black powder, and powder suspensions are almost equally successful). Diet Coke® works poorly with most methods.[7] It is tempting to speculate that the sugar in Sprite® gives it an enhancement advantage over Diet Coke® because of its stickiness.

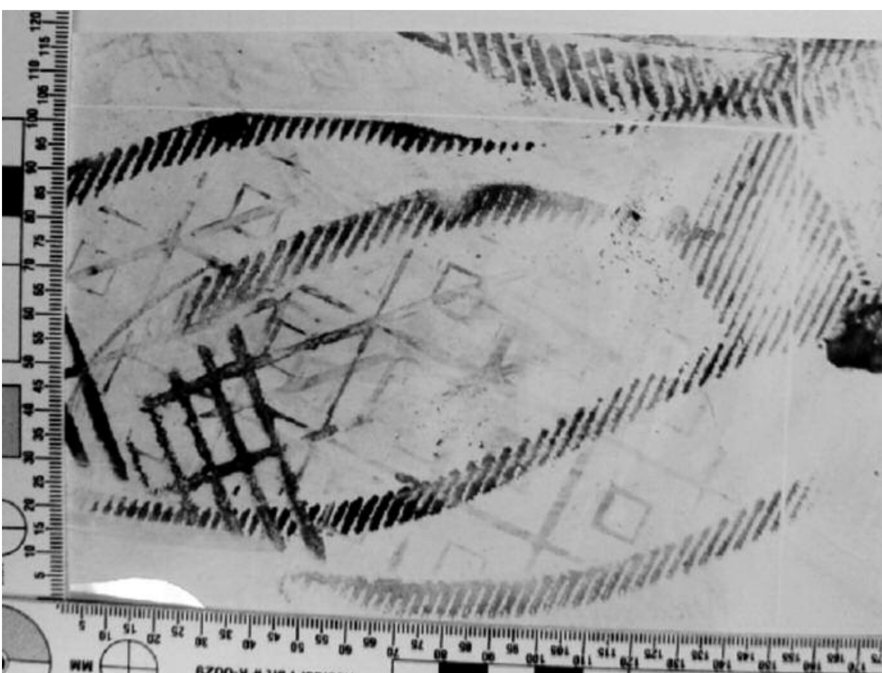
Chemically treated impressions are archived photographically. If an unenhanced impression can be transported to the laboratory, it must be preserved so that the impression will not be destroyed. A way to accomplish this is to treat it like all fragile evidence, which it is.

Three-Dimensional (3D) Impression Evidence

For forensic purposes, footwear impressions in a soft receiving surface where the impression is clear (3D impressions) have depth in addition to length and width. They are most commonly found outdoors in a soft or malleable receiving surface such as soil, sand, or snow. The quality—detail—of these impressions varies because of the following situations.

- The receiving surface's malleability, texture, and composition.
- The detail present in the source origin.
- The mode by which the impression was transferred to the surface.
- The effects of weather: temperature, rain, and snow.

Figure 3.7: Impression Dusted with Black Magnetic Powder and Lifted Using a White Gellifter



Certainly, the investigator has no control over how the impression was generated or its clarity, inheriting the impression at the scene. But the responsibility is to capture whatever detail that was originally present. Deciding what to cast may be obvious most of the time, but this isn't always the case. Generally, anything that has 3D detail, even impressions in water or snow, should be considered.

Impressions in snow can be cast, but this is not an "automatic" or fail-safe procedure, photography using a contrasting material, such as automotive primer, is a critical first step. One method is to use automotive gray primer paint to create contrast (care must be taken to shield the sun as the darker paint will absorb heat and melt the impression). Casting using Snow Print Wax spray (or powder) creates a thin wax covering over the impression, which can stabilize the impression sufficiently to allow casting (see Figure 3.8). The final cast should be photographed in case it cracks during transport.

While the process is simple, obtaining a successful and useful impression requires forethought and a strategy depending on the weather, the type of casting material, and the surface holding the impression. The goal, of course, is to capture the essence of the impression in order to make valid comparisons with known shoe impressions.

Figure 3.8: Footwear Impression in Snow

Photo courtesy of the Vermont State Police

A footwear impression sprayed with auto primer paint to bring out the pattern from the sole of the shoe.

FOR GREATER UNDERSTANDING

Questions

1. Name three reasons why pattern or impression evidence is overlooked.
2. What is associative evidence?
3. What is meant by the term “dry residue” impression?
4. Explain the difference between 2D and 3D impression evidence.
5. What is Snow-Print Wax? Why does it have forensic value?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. New York: Taylor & Francis, 2011.

Other Books of Interest

Bodziak, William J. *Footwear Impression Evidence: Detection, Recovery, and Examination*. 2nd ed. Pp. 17–20. Boca Raton, FL: CRC Press, 1999.

Hilderbrand, Dwane S. *Footwear, The Missed Evidence*. 2nd ed. Wildomar, CA: Staggs Publishing, 1999.

Websites of Interest

The *Gizmos & Gadgets* website features information and a short video on their Stun Gun Electrostatic Lifter product. —
http://www.csigizmos.com/products/dustlifting/stungun.html

Lecture 3 Notes

1. Hilderbrand, Dwane S. *Footwear, The Missed Evidence*. 2nd ed. Wildomar, CA: Staggs Publishing, 1999.
2. Photograph of Neil Armstrong’s footprint is courtesy of the NASA website (http://www.nasa.gov/audience/forstudents/k-4/home/F_Apollo_11.html). Information published by the United States government is in the public domain, and its use is appreciated.
3. Bodziak, William J. *Footwear Impression Evidence: Detection, Recovery, and Examination*. 2nd ed. Boca Raton, FL: CRC Press, 1999.
4. Ibid.
5. Wiesner, Sarena, Tsadok Tsach, Charles Belser, and Yaron Shor. “A Comparative Research of Two Lifting Methods: Electrostatic Lifter and Gelatin Lifter.” *Journal of Forensic Science*. 56(S1): S58–S62, 2011.
6. Ibid.
7. Home Office Scientific Development Branch. *Fingerprint and Footwear Forensics Newsletter*. Publication no. 24/08, May 2008.

Lecture 4

Impression Evidence: Vehicle Considerations

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 11, "Pattern Evidence I: Footwear Impressions."

Many crimes involve vehicles, some of which are not at the scene. Pattern evidence at the scene can be crucial in identifying the culprit vehicle.

In this lecture, we extend our discussion of impression evidence by vehicles from the perspective of tire-track impression evidence, its importance, and some of the scene parameters that crime scene units should consider when investigating vehicle-involved crimes.

Vehicle-Involved Scenes

Vehicle-involved scenes run the gamut of scene and crime types: homicides, sexual assaults, burglaries, drive-by shootings, terrorist events, and so on. Thus, identifying a vehicle used in connection with a crime or an incident should be a critical part of any on-scene investigation. Hit-and-run cases represent a common example of vehicle-involved crimes—vehicle to vehicle, vehicle to person, vehicle to other object—and typically involve vehicles that leave the scene. Here, damage to the vehicles (and the victim) creates the physical evidence critical for proving that a particular vehicle was at the scene; this evidence should be collectable either as packaged evidence or in the form of photographs and measurements.

Each vehicle involved in a crime has a factual history relating to how the vehicle was involved. The investigator's job is to sort through the facts and proceed logically and carefully, using intellectual and scientific tools to find the appropriate and correct probative evidence. In an abducted child case, there may be no evidence found inside the suspect vehicle proving the child had been there. Hopefully, the original investigation of the scene included a thorough investigation of not just the inside of the premises from where the child had been taken, but also outside, where the vehicle might have been parked. Hopefully, too, physical evidence of the vehicle's being there had been collected and the scene archived properly. An example of important physical vehicle evidence is tire tracks.

Tire-Track Impression Evidence—Evidence Often Overlooked

Earlier lectures concerning footwear impression evidence are applicable to tire-track evidence, which is also classified as two-dimension (2D) or three-dimension (3D). Like footwear evidence, the physical characteristics needed for meaningful criminalistic quality comparisons are categorized as class or individualizing, the former providing information about the tread design and the latter physical deformities imbedded in the tread of the tire from daily usage.

Enhancing tire-track evidence involves many of the same principles, such as photography and chemical enhancements. Done properly, photography can enhance an impression, as can chemical treatments that take advantage of the inherent chemical signature of the impression—minerals, such as iron and aluminum, organics, or bio-materials. Enhancements should more clearly visualize the impression.

There are differences between footwear and tire-track impressions in the differences in the forensic information they provide. Certainly each provides evidence of either the individual (shoe impressions) or of the vehicle (tire impressions) being at the scene, the latter suggesting the individual vehicle was used in the crime. Tire-track impressions are different because they can provide investigative information about the vehicle, while sneaker prints, for example, don't really narrow the field of suspects for investigators. The forensic information from tire-track impressions is important because it provides information that can help identify or find the vehicle.

Thus, examining tire-track evidence is critical for identifying, collecting, and documenting the physical evidence present to identify a suspect vehicle once it is found. Competent on-scene work is the only mechanism for obtaining this information. It should be pointed out that all of the physical evidence that might be present may not be present in all vehicle scene investigations. Regardless, the information should be looked for. The list in Figure 4.1 gives some suggestions for what to look for during the investigation.[1]

Figure 4.1: Information Available in Vehicle-Involved Investigations

- How was the vehicle maneuvered?
- What are the vehicle's characteristics?
  - –Stance
  - –Track measurements
  - –Wheelbase
  - –Tread wear indicators
    - Wear bars
      - –Lock
      - –Immediate surroundings
  - –Indicators of vehicle age
- How many vehicles and how many occupants were present?
- Were objects loaded or unloaded into/from the vehicle?
- Who was driving the vehicle?
  - –DNA from inside the vehicle or from fingerprints on the vehicle
- What was the direction of travel?
- What was the relationship of impressions at the scene to the arrangement of tires on the suspect vehicle?
- What is the position of the front of the vehicle?
  - –Impressions by front and rear tires
- Which impressions must be archived?
  - –Which track locations are most appropriate to archive?
- What other relevant evidence is present?
  - –Footwear impressions
  - –Fluid spills

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If the tire-track impressions are readily apparent, specific characteristics of the vehicle can be determined: stance, track width, turning radius, tread wear, and vehicle mechanical problems. The on-scene investigation is the only place to find these vehicular characteristics. Identifying the front and back tires is important. The age of the vehicle, old or new, is suggested by the number of different tire treads at the scene. A vehicle with four different tires might be older than one having tires all of the same tread design.

Why locate tire impressions from the front and rear tires? The information from these impressions can help pinpoint important physical characteristics of the vehicle. For example, if the vehicle was moving out of, say, a dirt parking lot, the turning diameter might be determined. As mentioned above, if it had four different tires, the investigator might be thinking "older" vehicle, but knowing which tire had which impression puts the tires on specific wheels. Determining the leading edge of front and back tires leads to measurements of the wheelbase and the track width, both characteristics of vehicles. If there are multiple tracks, identifying those coming from the suspect's vehicle is important.

The direction in which the vehicle was moving can be determined from the on-scene investigation by closely examining the tire tracks and then using known factors and common sense to show the direction of travel.

- Spinning tires from dirt, debris, or gravel kicked up by spinning wheels.
- Striations by sidewall in a furrow (in mud or snow) show which direction the tire was rolling.
- Tracks pinpointing where the vehicle stopped and backed up to change direction.
- Overlapping front and rear tire tracks can provide directional information.
- Flattened grass or small plants indicate direction.
- Tire tread patterns have directional indicators.
- Tires lift damp soil or snow slightly in the direction of travel.
- Tires deposit transferred material in the direction of travel.
- Mud, dirty water, or fluids splashed or thrown on other surfaces—vertical or horizontal—in the direction of travel.

Conclusively identifying the specific vehicle requires a detailed scientific comparison against the tire tread of a suspect vehicle. While identifying the specific vehicle requires recovering it and making direct comparisons, the scene investigator and laboratory analyst have recourses that can narrow the search among the possible universe of vehicles. Still, until the suspect vehicle is located and impounded, scene scientists/investigators must be certain to completely archive, collect, and preserve all tire-track evidence.

On-Scene Considerations

Investigators should consider anything at vehicle-involved scenes as having potentially probative forensic value. For vehicle-involved scenes, this is particularly important because there is a misperception that tire-track impressions have little forensic or investigative value. The value can only be realized if the investigators take advantage of the essential ingredients of a successful vehicular scene investigation. This means adhering to the basic principles of crime scene investigation (delineated in part one of this series).

Management of the scene should follow the guidelines set forth in lecture four of part one of this series. While these principles are inviolate, there are unique characteristics of vehicle-involved scenes. Specifically, these involve identifying, archiving, characterizing, and preserving the physical evidence necessary to answer the questions posed in Figure 4.1.

Archiving (photographing, sketching, video, 3D-imaging) tire-track and other vehicle-involved scene evidence is critical; each photograph must tell the story the scene offers. This means establishing or overview shots must completely illustrate the relationship of the tire-track impressions to the overall scene. If the crime involves the burglary of a convenience store, for example, the tire tracks in the parking lot must show them in relation to the front of the store as well as to the street. Mid-range photos must illustrate properly how the tire-track impressions relate to other evidence nearby, such as footwear impressions, if present, and their relationship to the tire-track impressions must be absolutely unambiguous. Scales should show distances involved and these should be included in the photographs (one without scales and one with). If evidence markers are going to be used, the initial photographs should be taken without the markers in place and then with them. Close-up photographs must include at least twenty-four inches of each impression taken with and without scales in the plane of the impression. Each photograph should identify each tire, so that there is no ambiguity concerning its location on the vehicle (for example, right front, right rear, and so on). Also, tire-track-impression photographs should capture all four tires. Each photographic series must have specific information, and each photograph must have its specific identifying information[2]—case number, location, photographer, date, time, arrows to indicate front of vehicle, and north or south directional indicators.

Generally, scene sketches conform to the archiving principles. The vehicle sketch must be complete and sufficiently detailed to permit someone to identify specific vehicle characteristics; this depends on the amount and detail of the tire-track impressions present. The sketch should include measurements that provide specific vehicle-related information (for example, wheelbase, stance, and so on), and this should be included on the sketch or over several sketches. Thus, obtaining these critical measurements from relevant impressions must be done at the scene. Sketches should document the presence of scene-related as well as non-scene-related impressions. All tire track impressions in the dirt must be included in the sketch. The evidence impressions related to the specific investigation, if they can be identified, should be highlighted.[3]

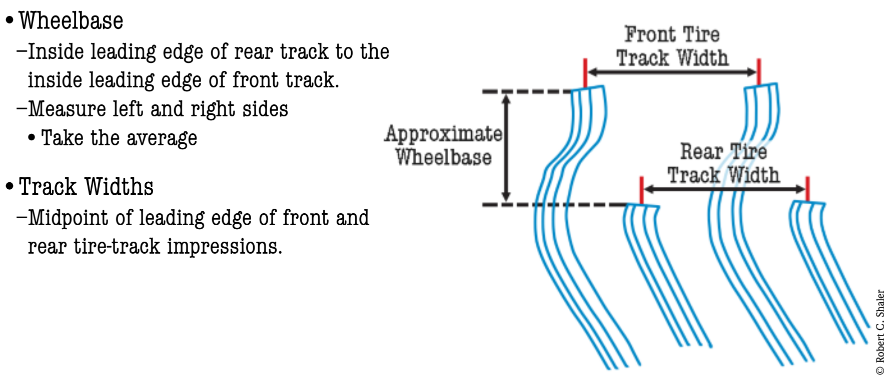
Measurements should be obtained that can, if possible, lead to identifying specific characteristics of an unknown vehicle. Among others, these include the following.

What to Measure

Wheelbase

The wheelbase of the vehicle is defined as the distance between the leading edge of the front and rear tires. Figure 4.2 illustrates how to determine the wheelbase from tire-track impressions at the scene.[4]

Figure 4.2: Wheelbase Determination



Front and Rear Track Widths

The front and rear track widths are defined as the distance between the middle of the leading edge of the front and back tires, respectively. Figure 4.2 illustrates how to determine the front and rear track widths from tire-track evidence at the scene. Mechanical issues with a vehicle can affect how these impressions appear at the scene.

Camber

Among others, one is camber, which is the "tilt" of the tires as they rest on the ground. Figure 4.3 shows the differences between normal and abnormal camber, which can be positive or negative, each signifying improper alignment or worn front-end parts of the vehicle. Positive camber is defined as the tires tilted further apart, "out," at the top. Negative camber is defined as the tires tilted closer, "in," at the top, each with respect to what the camber is supposed to be.[5]

Figure 4.3: Camber Affecting Track Width

- Camber
  - –Tire tilt inward or outward of tire resting on the ground.
    - Measured at the top from true vertical
- Causes of Improper Camber
  - –Improper wheel alignment
  - –Worn front-end components

Turning Diameter

The turning diameter is defined as the diameter of the circle made when the vehicle is driven in a circle. It, too, can be determined from the measurements taken of the impressions at the scene. Importantly, not all tire-impression evidence will have sufficient information to make these measurements. A significant amount of impression arc is necessary in order to calculate the turning diameter, which punctuates the importance of preserving the entire impression during the investigation. The measurements are made at the scene, although they could be made from 3D-imaging equipment employed at the scene or from photographs analyzed in the laboratory or from aerial photographs above the impression, if known size markers are visible.

Tread Design Width (Arc Width)

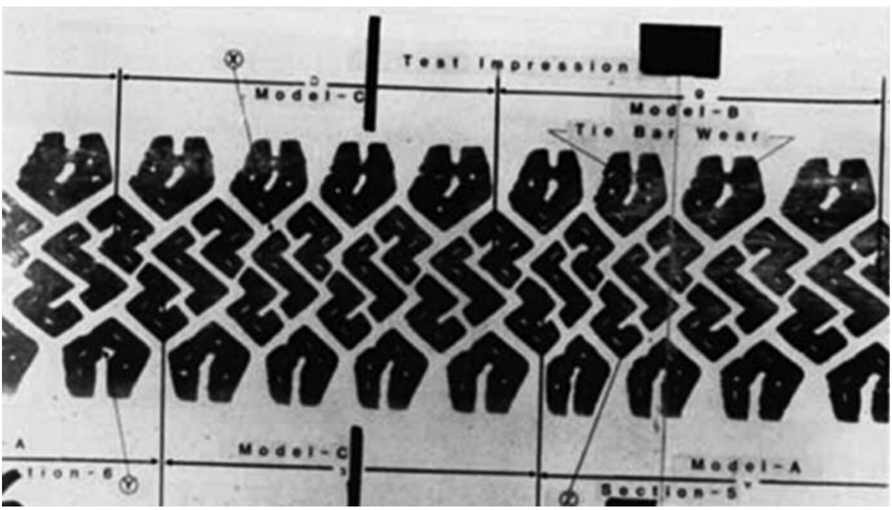
The tread design width is defined as the measurement from one edge of the design to the other. These measurements should be made at the scene and from the actual impression. This information is important so that manufacturers can help investigators identify an unknown impression.[6]

Tread Depth (Skid Depth)

This is defined as the depth of an impression based on the manufacturer's non-skid design of the tread. In new tires, these can range from $^{11}/_{32}$ to $^{12}/_{32}$ of an inch, although mud and snow tires are deeper and will be as much as between $^{14-16}/_{32}$ of an inch. These measurements can help eliminate suspect vehicles. For example, if the tread depth measured at the scene is, say, $^{8}/_{32}$, and a suspected car is $^{12}/_{32}$, the suspected car could not have been involved in the crime.[7] Performing these measurements at the scene is a matter of using a scale calibrated in $^{1}/_{32}$ of an inch (or a 15 mm forensic scale). Lower the scale into the impression and read the depth from the scale. Castings made from the impression can also be used to determine the tread depth.

Tire Circumference: Suspect Vehicle

If the tire-track impression is long enough, it might be possible to approximate the tire's circumference by finding an accidental, repeated characteristic, such as a gouge or cut, in the imprint. The distance between repeated marks is defined as the rolling tire circumference.[8, 9] To use this characteristic of the tire, it must be repeated so that there is at least one full revolution of the tire. This is important because comparing apples to apples is the only way to obtain correct data. That is, the same measurement made at the crime scene will be from, say, gouge to gouge as seen in the impression. The on-scene measurement will differ from one taken by wrapping measuring tape around the tire, which will be larger. The reason is that the impression is flat but the tire has a curved arc.[10]



An inked test impression of a tire showing imperfections that, under the right conditions, can provide probative evidence that a specific vehicle was at the scene of a crime. Note the comment on the upper-right area under the black rectangle that indicates "Tie Bar Wear."

Impressions Made in Substances Other Than Dirt

Like the sole of shoes, 2D impressions of tire tracks are visible because contaminants adhere to the tread; dirt and dust being the most common. Other contaminants also create impressions: water, grease, oil, or blood. Each leaves a visible impression that can be enhanced; the enhancement method will differ depending on the contaminant.[11] There is a variety among which to choose, so making intelligent, well-thought-out choices is important. Certainly, archiving the impression photographically is step one, which can be followed by seriously considering the enhancement choices coupled with an understanding of the variables offered by the scene: the scene surface, the chemistry of the impression material (dirt, oil, blood, and so on), and the chemistry of the enhancement method.

FOR GREATER UNDERSTANDING

Questions

1. Describe the forensic importance of tire-track impression evidence versus footwear impression evidence.
2. How many inches of a tire-track impression should be photographed?
3. From tire-track evidence, how can one determine the circumference of the tire?
4. What is the wheelbase? How is it determined from tire-track evidence?
5. What is the tread depth? What can determining it from on-scene evidence tell you about a specific vehicle's tires?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

McDonald, Peter. *Tire Imprint Evidence*. Boca Raton, FL: CRC Press, 1992.

Nause, Lawren. *Forensic Tire Impression Identification*. Ottawa, ONT: National Research Council of Canada, 2001.

Lecture 4 Notes

1. Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Chapter 11: "Pattern Evidence I: Footwear Impressions." Boca Raton, FL: CRC Press, 2011.
2. Nause, Lawren. *Forensic Tire Impression Identification*. Ottawa, ONT: National Research Council of Canada, 2001.
3. McDonald, Peter. *Tire Imprint Evidence*. Boca Raton, FL: CRC Press, 1992.
4. Shaler, Robert C.
5. Ibid.
6. Nause, Lawren.
7. Ibid.
8. McDonald, Peter.
9. Nause, Lawren.
10. Ibid.
11. Shaler, Robert C.

Lecture 5

The Biological Crime Scene, Part One

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 13, "The Biological Crime Scene: It's Not Just About DNA."

Biological evidence is critical in many investigations because of the possibility of finding DNA. But finding it requires using all of one's technological and intellectual skills.

Consider the totality of the evidence at a crime scene. Failing to locate biological evidence, as opposed to other evidence that might not be there, is different because of the lofty importance DNA evidence has in our legal system. Why? It can identify someone to the exclusion of everyone in the world, which is why investigators often focus on finding biological evidence. This works because DNA profiles from biological evidence collected at the crime scene are uploaded into an FBI-maintained database—CODIS (Combined DNA Indexing System). Once in the system, scene profiles can be matched to other crime scenes, convicted felons, arrestees, or missing persons. It should be no surprise that DNA is coveted as evidence from both investigational and legal perspectives. Every crime scene involving people has biological evidence considered from this perspective: Anyone entering a room brings something of themselves with them. When they leave the room, they leave something behind. Certainly, whatever is left behind might be difficult or even impossible to find.

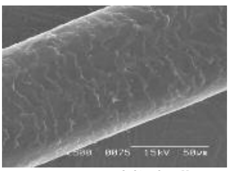
An investigator finds a young male lying on the floor. The deceased has no head hair and a large contusion on the side of his head. There are no obvious bloodstains and no apparent active bleeding: just a trickle of blood on the deceased's cheek. There is no sign of a struggle. Outside the back door and lying on the pavement is an old, broken brick with rough edges. The location is not particularly unusual and the brick would not normally be considered the murder weapon. Examining the brick casually reveals nothing except, perhaps, some dirt: certainly no hair or obvious blood or skin. But this is, indeed, the murder weapon, and biological evidence is present. In fact, by definition, biological evidence must be present. Some investigators will fail to collect the brick, and others might, just to be safe. Both will believe the brick has no evidentiary value. The forensic scientist can find shed skin cells lodged in the crevices of the brick, which is not yet an on-scene procedure. The message is that biological evidence is always present.

Categories of Biological Evidence

The most commonly occurring examples of biological evidence usually come from humans and animals because people are usually the victim or the perpetrator of a crime and since people have pets, their biological material may also be present. The illustration in Figure 5.1 lists examples of forensically important biological evidence, some of which is commonly or not so commonly encountered.[1]

Figure 5.1: Forensically Important Biological Substances

- Common Examples
  - –Blood: Human and animal
  - –Semen
  - –Saliva
  - –Urine
  - –Feces
  - –Vomit
  - –Hair



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Scanning electron microscopy view of a healthy human hair.

- The Not-So-Common Examples
  - –Bacteria
  - –Plant material
  - –Pollen
  - –Viruses

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Some forensically important biological evidence occurs more often than others, such as blood, hair, semen, fingerprint residue, or sloughed-off cells; the latter usually are not considered examples of biological evidence. Fingerprint residue is important because of friction ridge detail and sloughed-off cells are not usually visible. However, fingerprints and sloughed-off cells contain DNA. So, when a perpetrator holds a weapon or picks up an object with an uncovered hand, cellular material transfers from the hand to the object. In fact, increasingly modern forensic DNA analysis involves what has become known as "touch evidence." This is why scene investigators must consider all evidence from a biological perspective, even if it is invisible to the naked eye.

Finding Biological Evidence

Arguably the most important quest, given the critical importance of DNA, is to find and collect anything of biological significance. Biological evidence is a critical element of the macroscene (bloodstain patterns, droplets, and so on) and the microscene (pollen and bacteria, for example). The challenge is to find that which is important contained within the milieu of all that is present, a huge challenge. The first consideration is to use the tools available, the most important being your brain. Secondarily, those having the appropriate scientific education, experience, and minds that think creatively and skeptically and those who understand the underlying science behind the technology and are aware of and know how and when to apply it will be the most successful.

Early scene investigators had few tools and limited technology with which to find biological evidence. This is why they used their ability to think combined with their experience and knowledge of crime types to find evidence.

Blood

The most commonly occurring type of biological evidence, blood is found at a who's who of crime types: homicides, sexual assaults, burglaries, assaults, and others. Testing to determine if something that looks like blood at a crime scene is blood (or another type of biological evidence) involves experience and the use of tests called presumptive tests, a term that refers to a test result that suggests whether a particular stain might be blood and have investigative value. These are not confirmation tests. Let's consider some of the presumptive tests for blood.

The oldest is the human eye. Most of us think of blood as a red substance, but dried blood can be red, brown, yellow, green, or black. So understanding the conditions under which these transitions occur is important. Fortunately, the eye is not a stand-alone instrument, but when we look at something red our brain interprets the color and then determines (presumptively) that the substance is blood. This is an observation made in the context of our experience, which is being tested. Like eyewitness testimony, our experiences are not infallible or applicable to all situations. For an experienced scene investigator, observing something red in the context of the crime, such as impact spatter above a body, has forensic value. It does not mean that the spatter is composed of blood, though it probably is. So, being "certain" that something is blood does not make it so. The human eye is not a confirmatory test, but coupling observational skills with experience narrows the range of possibilities. Examining evidence with the unaided eye is a good first approach, but technology can enhance the likelihood of finding blood.

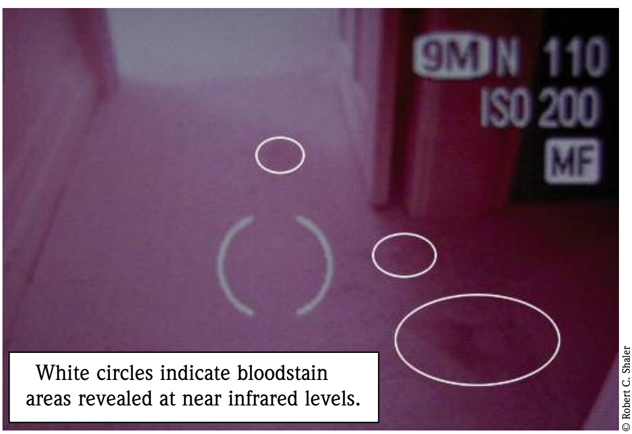
Light enhances our ability to "see" evidence where it would normally be invisible. Oblique lighting is an example of how light helps find impression evidence. Alternate light sources (ALS) are portable, high-intensity instruments with tunable wavelengths that can highlight categories of evidence. These instruments are a versatile resource for investigators because they can enhance the ability of the human eye to "see" better. The molecules that make up the evidence absorb specific wavelengths of light, making the evidence appear dark. If the molecules absorb and then lose energy, it can be seen as light—fluorescence.

With blood, the ALS has minimal use because no wavelength in the visible spectrum causes blood to fluoresce. However, there are "tricks," depending on the surface on which the blood lies. For example, the 415 nm setting on the ALS makes the blood appear darker on light backgrounds,[2] and enhances its apparent visibility. This occurs because dried blood absorbs light at 415 nm, making it dark instead of reddish or reddish brown. However, blood on dark surfaces is difficult to see and is easily missed. One method is to use the ALS to subtract out the background using different wavelengths (colors). If successful, the blood will appear dark against a lighter background. An example would be dried blood on a red wall, where the contrast between the blood and the wall can be minimal. Using an appropriate ALS setting can lighten the background—light blue—the result being a dark blood spot on a light blue background.

Fortunately for scene investigators blood absorbs infrared light, which makes it appear dark. This can be useful to help visualize blood on dark backgrounds or, sometimes, on dark, shiny surfaces. Because digital cameras can be made to see only infrared (IR) light, they expand an investigator's sight range into the real-time near infrared, making these cameras indispensable tools for on-scene investigations when the ALS is of little help.

Stains highlighted with IR light can be tested to determine whether it might be blood. The photograph in Figure 5.2 was taken of the LCD viewer of an IR camera (Fuji 9000S converted to IR mode).[3] The image is of a red carpet with bloodstains that were invisible to the naked eye or using the ALS. The stains are visible in the LCD on the IR camera.

Figure 5.2: Photograph of LCD of an IR Digital Camera



For the technique to work, the surface must not absorb in the infrared region. If it does, both the blood and the surface will appear dark. It is simple enough to find whether the surface absorbs. Simply turn on the digital IR camera and look through the LCD viewer. If the surface appears dark, it absorbs in the IR. If it appears lighter, it does not, and, if present, the blood should be visible.

Chemical tests that react with blood were developed in the mid nineteenth century and are still used to determine whether an unknown stain might be blood. A positive chemical test means that there is an approximately 95-percent chance that the unknown stain is (or contains) blood. This is important because many reddish or dark stains at a crime scene are not blood. Each test works on the same principle and can be divided into two categories: those that produce colors and those that produce luminescence.[4, 5] The former include a range of dyes that turn color in the presence of hemoglobin, a protein component of blood, and peroxide (typically hydrogen peroxide). Many of these reagents are available commercially; the most common include phenolphthalein (Kastle-Meyer Reagents), leucocrystal violet (LCV), and tetramethylbenzidine (TMB).

The latter category is chemicals that react with hemoglobin and peroxide to produce light, chemiluminescence: Luminol,[6] BlueStar™, and fluorescein. They are used at crime scenes where clean-up is suspected. An example of BlueStar's™ luminescence is in Figure 5.3.[7] The sink area in the photograph had been washed with water and bloodstains were not visible before spraying with BlueStar™.

Figure 5.3: BlueStar Enhancement of Washed Bloodstains

© Robert C. Shaler

The florescent blue areas indicate bloodstains revealed by use of BlueStar™ chemiluminescence.

Presumptive blood-testing reagents are useful because they provide immediate investigative information. Substances that have peroxidase activity, such as horseradish, will give false positive reactions.

Confirming the Presence of Human Blood

Lateral flow immunochromatography is a rapid technique for identifying small amounts of specific molecules. Its forensic application has been largely used to identify forensically important biological substances—blood, semen, saliva, and urine. The specific tests can be conducted on-scene, and unlike presumptive tests, they specifically identify unknown stains as human blood (some cross react with ferret blood), semen, or saliva (identify salivary amylase).

The quickness, ease-of-operation, specificity, and sensitivity of these immunochromatographic cards makes it tempting to avoid the traditional chemical tests entirely. If cost is not an issue, this might be a best choice because these tests confirm the presence of human blood in a single test. Importantly, the used immunochromatographic card and the stain extract needed to run the test can be submitted to the laboratory for DNA analysis.[8, 9] Investigators should be aware of product differences among manufacturers by testing for sensitivity and specificity as part of the validation aspect of a comprehensive quality-assurance program.

Collecting and Packaging Blood Evidence

The mechanism used to collect and preserve blood evidence is critical. If done incorrectly, the result can compromise or destroy the evidence. There are seven invariant rules:

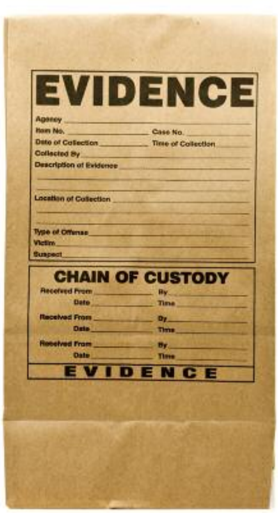
1. Always wear protective clothing—face masks, gloves, proper outer wear, and shoe/boot covers.
2. Dry all blood evidence. If that is not possible, transport it to the forensic laboratory as soon as possible, ensuring that it does not contact other evidence.
3. Never package blood evidence in plastic. Always use paper.
4. Package each item of evidence individually. Never mix items.
5. Never allow adjacent bloodstains (even if dry) to come into contact with other stains on the same or other items of evidence.
6. Store all biological evidence in a cool, dark place, if possible. This means keeping the evidence out of sunlight and heat, such as in a police car or crime scene unit vehicle on a hot day while processing the scene.
7. Collect the entire sample, if possible. This may not be possible because of the size or fixed location of an object. If this is not possible, cut the entire stain from the larger item and document the location photographically. If necessary, collect evidence on lightly moistened swabs.

Following these rules ensures that blood evidence—biological in general—will be collected and preserved properly. Blood evidence also is seen as patterns that have important interpretative information. Collecting blood properly depends on the form it takes: pools, droplets, trails, swipes, castoff, weapons, furniture, and clothing.

If possible, the entire bloody object should be collected and packaged, which gives the laboratory the opportunity to decide which stains are important. If the investigator makes that decision at the scene by choosing one stain from, perhaps, a group of dried stains on a piece of furniture that contains more than one individual's blood, the second person's blood might never be analyzed. This will compromise the ultimate scene analysis, the understanding of the ground truth of what happened, and the reconstruction of the events.

Collect dried droplets by scraping into an appropriate collection vehicle such as a druggist fold bindle or coin or glassine envelope. Always record the temperature, humidity, and the conditions where the stain was located (windy, sunlight, shade, and so on). If the stain is large, such as a wet pool, absorb a small amount onto a lightly moistened cotton swab, place it into a small swab box (a small rectangular box with holes near one end like those used to dry vaginal swabs in sexual assault cases) and allow it to dry. If the evidence is a blood trail, determine the direction of travel, photograph the diagnostic droplets to preserve the information, and then collect representative droplets from the beginning, middle, and end of the trail by swabbing them onto a moistened cotton swab or by scraping them into separate envelopes. Package them separately.

Package dried blood on clothing by folding the garment around brown or white wrapping paper. Make certain that individual stains on the garment do not come into contact with other stains. After folding the evidence, place the entire garment into a separate paper evidence bag. Label the bag appropriately.



FOR GREATER UNDERSTANDING

Questions

1. List three presumptive tests used to locate blood at a crime scene.
2. Why does the ALS have minimal application for finding blood at the scene?
3. What is lateral flow immunochromatography? What value does it have for on-scene work?
4. What are the seven invariant rules for collecting and packaging biological evidence?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Li, Richard. *Forensic Biology: Identification and DNA Analysis of Biological Evidence*. Boca Raton, FL: CRC Press, 2008.

Lecture 5 Notes

1. Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Chapter 13: "The Biological Crime Scene: It's Not Just About DNA." Boca Raton, FL: CRC Press, 2011.
2. Stoilovic, Milutin. "Detection of Semen and Blood Stains Using Polilight as a Light Source." *Forensic Science International*. 51(2): 289–96, 1991.
3. Shaler, Robert C.
4. Johnston, Emma, Carole E. Ames, Kathryn E. Dagnall, John Foster, and Barbara E. Daniel. "Comparison of Presumptive Blood Test Kits Including Hexagon OBTI." *Journal of Forensic Science*. 53(3): 687–89, 2008.
5. Tobe, Shanan S., Nigel Watson, and Niamh Nic Daeid. "Evaluation of Six Presumptive Tests for Blood: Their Specificity, Sensitivity, and Effect on High Molecular Weight DNA." *Journal of Forensic Science.* 52(1): 102–9, 2007.
6. Quickenden, Terence I., and Paul D. Cooper. "Increasing the Specificity of the Forensic Luminol Test for Blood." *Luminescence*. 16: 251–53, 2001.
7. Shaler, Robert C.
8. Roy, Reena, and Tam Ho. Forensic Science Program, Pennsylvania State University, personal communication.
9. RSID. "Developmental Validation of a Novel Lateral Flow Strip for the Rapid Identification of Human Blood, Rapid Stain Identification–Blood, RSID™–Blood." (2010) — http://www.ifi-test.com/pdf/BloodValid.pdf. Accessed 2/4/11.

Lecture 6

The Biological Crime Scene, Part Two

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 13, "The Biological Crime Scene: It's Not Just About DNA."

Semen is the second most common biological evidence found at crime scenes. Finding it requires knowledge of the scene events and understanding of why and how technology visualizes the evidence.

Categories of Biological Evidence Continued

Semen

The second most prominent class of biological evidence found at scenes is semen, usually located using an ALS with a wavelength that causes semen to fluoresce. Typically, the scene investigator wears orange goggles and uses a blue light set at a wavelength of approximately 450 nm. All investigators know what semen is, but few have a complete understanding of its origin biologically or its forensic potential. Forensic investigators also know that semen plays an important role in identifying assailants in sexually motivated crimes because of the DNA present in the spermatozoa. If the DNA profile from spermatozoa cannot be matched to a previously incarcerated felon in CODIS, it has little investigative value. However, learning that the semen has an illicit drug profile may provide important investigative leads, such as people to interrogate. Likewise, a smoker has nicotine metabolites present, which gives personal information about the assailant.

Historically, forensic scientists have used what is known as the acid phosphatase (AP) test to presumptively identify semen from evidence received from the crime scene or vaginal/rectal/oral swabs from the hospital or medical examiner. A positive AP test indicated that semen might be present. Confirmation was done by observing spermatozoa microscopically. This analytical sequence changed for forensic laboratories in the 1970s with the discovery of a semen-specific protein known as p30 by forensic scientists[1, 2] and prostate specific antigen (PSA) by clinical scientists,[3] determined immunologically.

At the scene, there is neither the time nor the resources to perform microscopic or, historically, immunological analyses for spermatozoa. In fact, that is not the job of the scene investigator: find the evidence and transport it to a forensic laboratory for analysis. In the '50s and '60s the "crusty feel" of dried semen was a quick check for the presence of semen. At that time laboratory scientists used this same tactile "test" because it was fast and could be easily performed on evidence where semen might logically be expected, such as bed sheets. Another on-scene technique employed was the first true alternative light source, the black light, also known as the Woods light.[4] Shortwave ultraviolet light caused semen to fluoresce, and it worked well for semen stains on unwashed light, as well as on dark, fabric. It did not work on light, detergent-washed fabric because detergents in the fabric interfered with the luminescence of the semen.

The same AP test employed in the forensic laboratory to presumptively identify semen was adapted for scene use, and it is essentially like the chemical tests for blood. Interpreting it was much the same, too, and was based on the time it took to produce a specific color. It was and still is a presumptive test.

At the scene, confirmatory tests were not available for dried semen testing until recently. The immunochromatographic cards described for blood are also available to identify the presence of semen proteins, p30, also known as prostate specific antigen (PSA) by Abacus Diagnostics,[5] and semenogelin, manufactured by RSID.[6] The proper use of the cards can quickly identify human semen at the scene. The acid phosphatase test, which is still useful, does not identify human semen; it identifies acid phosphatase, a high-level component of semen, and is a presumptive-only test. Figure 7.2 is an example of an immunochromatic graphic card for saliva.

Searching for Semen

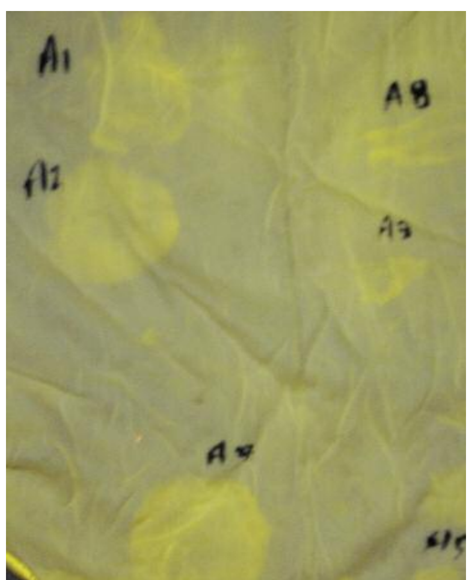
A rationale or decision tree should be in place for deciding how to approach locating biological evidence at a scene. Certainly the first line of attack is logic, which leads to where semen might be. At obvious sexually motivated crimes, searching for semen takes place in the most logical places: beds, sofas, and car seats, for instance. However, there are non-sexually motivated scenes at which a perpetrator might masturbate, urinate, or defecate. In fact, burglary scenes have a higher incidence of semen than one might expect. For whatever reason, burglars sometimes masturbate and inadvertently leave their biological signature. So searching for semen should not be confined to the obvious crime type and should not be a one-step, check-the-bedroom-only endeavor.

There is still the question of how an investigator should search for semen evidence. Certainly the easiest and probably the best method is to use the ALS as a first line of attack. Even when using the ALS, there should be a rationale, perhaps a written procedure, for deciding which ALS-positive stains to test further and how and which to collect for the laboratory. There should be a "cheat sheet" of wavelengths to use with accompanying photographs of what to expect. It might seem surprising but there really are alternative approaches. In each of the following, the ALS is the first avenue of analysis, but it should never be forgotten that the ALS is useful for locating semen as well as other biological evidence, such as saliva, urine, and trace evidence.

- Use the ALS to locate possible semen, saliva, or urine stains and allow the laboratory to decide which to test further. This is by far the safest approach because it leaves the choice of subsequent DNA analysis to the laboratory. Mark and photograph any stains that the ALS highlights.
- Use the ALS to locate possible probative stains and then use the acid phosphatase test to determine which might be semen. The laboratory would likely re-test the stain with the ALS and the AP test and then perform DNA analysis, if warranted.
- Use the ALS followed by an immunochromatographic test (AP test is not used). Since the definitive/confirmatory immunological test is performed, a positive test shows the stain analyzed is human semen. However, a negative immunochromatographic card test suggests the ALS-highlighted stain is not semen. The card result might be erroneous because of something known as the “Hook Effect.” A second test for AP might be positive. If only the ALS is used on-scene, the laboratory will re-test the stain to confirm the presence of semen. False negative results can occur with old stains that have been exposed to environmentally detrimental conditions for extended periods of time. It is also possible for the AP and the immunochromatographic card tests to be negative on older stains, especially those exposed to excessive environmental insults.

When ALS-highlights something that could have a biological origin, the area should be marked by circling the area or highlighting the location with a marker or an arrow sticker to illustrate where the positive presumptive test result was obtained. It does not mean that this is the only stain present or that it might be semen. It means only that an ALS highlighted something that might require further analysis. The investigator should initial and date the evidence and archive the marked evidence photographically so that the laboratory knows exactly which stain on the evidence gave a positive ALS. There should be no guesswork for laboratory scientists.

Figure 6.1: ALS Highlight of Semen on Slip



Photograph by Ralph Ristenbatt III. Used with permission.

An example of an old stain is shown in the photograph in Figure 6.1. It was taken of a young girl’s slip using an ALS.[7]

The slip was taken from the body of a young girl who had been attacked, raped, and murdered forty-plus years before the ALS analysis. The areas in yellow and marked with letters and numbers (A1, A2, and so on) are luminescent areas highlighted by the ALS. These were semen stains. The AP test, evaluated using most established standards, was negative—it took a long time for the reagent to show a very weak purple color. This was expected because the stains had been stored improperly for forty years. The only tests giving positive results were the ALS and an immunological test for prostate-specific antigen (p30). Dissolving the stain to give the positive anti-p30 test result required dissolving the stain for an extended period of time. For that reason, if the test had been done at the scene using an immunochromatographic card, the test result would likely have been negative. Subsequent DNA testing using LCN (low copy number) techniques gave a full STR (short tandem repeat) profile and identified the murderer forty-plus years later. Standard STR testing gave only a partial DNA profile.

The steps necessary to use an ALS to locate biological fluids on garments is listed below.

> Examine the evidence using the 450 nm wavelength of the ALS (the CSS and other wavelength settings on the MiniScope™ 400 can highlight semen or other fluorescing biological substances—some without using goggles—but the preferred method is to use the 450 nm setting and orange barrier filters or goggles). The schematic in Figure 11.3, part one of this series, illustrates the process.

Technology on the horizon may have dramatic effects on how scene investigations proceed. Recent publications suggest that on-scene DNA analysis may be possible. When or if this becomes a reality, the dynamic of crime scene investigations will change dramatically because DNA profiles produced at the scene could be uploaded directly into a local, searchable, DNA profile database. The subsequent investigative result may identify the perpetrator or provide links to one or more crimes. This rapid, investigative information can be critical for solving crimes. Simply knowing how many different bloodstains or semen stains there are on a bed sheet can alter and speed the investigative process by providing information quicker to investigators.

Collecting and Packaging Semen Evidence

The invariant rules discussed for collecting and packaging blood evidence apply equally for semen evidence. The packaging guidelines are also the same. Generally, semen evidence at the scene is typically found on tissue paper, clothing, towels, bed sheets, pillows, blankets, furniture, and droplets on the floor or on the skin of a deceased individual or live survivor, and it is dry. If not, it should be air dried. Collecting it can be done by taking the entire, dried stain or by swabbing it onto a lightly moistened sterile cotton-tipped swab designed for semen evidence. The swabs can be dried at the scene using a drying device designed for drying swabs at the scene or by placing the swab into a cardboard holder also designed for that purpose.[8] Guidelines for collecting semen evidence found on various surfaces—whether liquid or dry—are shown in Table 6.1.[9]

Table 6.1: Collecting Semen Evidence at the Scene

Semen at the Scene	Collection Procedure
Semen and Seminal Stains Liquid Semen Evidence Found at a Scene Example: droplets on floor	Archive all semen evidence: notes, photography, videotape, and sketching. Depending on surface, collect in syringe or disposable pipette. Transfer to clean, sterile tube. Label tube with the case and item number, date, time, location, and name of the collector. Keep refrigerated and submit to laboratory ASAP. Or: Absorb liquid semen onto clean cotton cloth. Air dry, package, seal, and label appropriately with name of collector, date, case number, description of item, and location where found.
Seminal Stains on Movable Objects Examples: panties, clothing, bed sheets, pillows, and movable objects	Collect as is. If stain is wet, air dry thoroughly. Package items separately in a clean paper container. Refrigerate packaged items if possible. Submit to laboratory ASAP.
Seminal Stains on Large Objects That Can Be Cut Examples: furniture and carpet	Cut stain from items document, and package as above. Use disposable scalpel, new blade or scissors to cut stained area. Place each cutting into separate piece of clean paper. Make druggist fold to secure evidence. Place the druggist fold into paper container, seal, and label.
Seminal Stains on Immovable, Nonabsorbent Surfaces Examples: floors, counters, and metal surfaces	Document stain. Use disposable scalpel or new blade to scrape stain onto clean paper, and fold the paper into a druggist fold. Place druggist into own paper container, seal, and label properly.

FOR GREATER UNDERSTANDING

Questions

1. What is the AP test?
2. Is the AP a confirmatory test for semen?
3. In an era where the ALS is the primary search tool for finding biological evidence, what value does it have in helping to locate semen evidence?
4. What method is used to positively identify human semen at a crime scene?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Li, Richard. *Forensic Biology: Identification and DNA Analysis of Biological Evidence*. Boca Raton, FL: CRC Press, 2008.

Lecture 6 Notes

1. Graves, Howard, George F. Sensabaugh, and Edward T. Blake. "Postcoital Detection of a Male-Specific Semen Protein: Application to the Investigation of Rape." *New England Journal of Medicine*. 312: 338–43, 1985.
2. Sensabaugh, George F. "The Isolation and Characterization of a Semen-Specific Protein from Human Seminal Plasma: A Potential New Marker for Semen Identification. *Journal of Forensic Science*. 23: 106–15, 1978.
3. Wang, M.C., L.A. Valenzuela, G.P. Murphy, and T.M. Chu. "Purification of a Human Prostate Specific Antigen." *Investigative Urology.* 17: 159–63, 1976.
4. Wood, R.W. "Communications Secretes au Moyen de Rayons Lumineux." *Journal de Physique (Theoretical and Applied)*. Vol. 9: 77, 1919.
5. Abacus Diagnostics™. Semen Identification Test. — http://www.abacusdiagnostics.com/semen.htm. Accessed 2/5/11.
6. IFI Independent Forensics. RSID™-semen. — http://www.ifi-test.com/rsid_semen.php. Accessed 2/5/11.
7. Graves, Howard, et al.
8. Sirchie™. EZ-Dry—Swab Box Kit. — http://store.sirchie.com/EZ-DRY-Swab-Box-Kit-P1687.aspx. Accessed 2/5/11.
9. Promega™. Collection and Preservation of DNA Evidence. — http://www.promega.com/geneticidproc/ussymp7proc/0704.html. Accessed 2/5/11.

Lecture 7

The Biological Crime Scene, Part Three

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 13, "The Biological Crime Scene: It's Not Just About DNA."

Finding biological evidence other than blood and semen can be equally as important. Examples include saliva, feces, vomit, hair, plant material, and microorganisms. Understanding how to handle this evidence can be crucial in solving a crime.

Categories of Biological Evidence Continued

Saliva

Historically, identifying a dried saliva stain meant identifying the salivary component in the largest concentration, the enzyme alpha amylase (AMY 1). The problem is that, like AP, amylase occurs in most forensically important tissues. Identifying saliva in unknown stains requires testing to ascertain the amount of amylase present and its genetic origin. The human body produces two different amylases: One occurs in saliva and the other in the pancreas. Still, the on-scene identification of saliva has not been historically a target of investigators. One reason is that robust, easily employed techniques have not been available. And when found, it was likely associated with sexual assault evidence such as a bite mark.

This changed somewhat with high-powered ALS's that cause saliva to fluoresce, albeit weakly. Once a fluorescent area is located, presumptive tests for amylase can show that saliva might be present. On dark surfaces or garments, it is sometimes possible to visualize saliva stain using oblique lighting from an ALS. The photograph in Figure 7.1 illustrates this with an ALS white light held obliquely to highlight a bite impression on a Navy pea coat.[1] The light color is dried saliva. Notice the teeth impressions in the fabric (white arrows).

Figure 7.1: ALS Highlight of Dried Saliva on a Pea Coat

Photograph by Ralph Ristenbatt III. Used with permission.

The three methods for presumptively identifying saliva are the Phadebas test, the starch-iodine diffusion test, and the immunochromatographic card. The Phadebas test is commercially available in a simple, scene-forward format.[2] The starch-Iodine diffusion test requires that the scene scientist/investigator prepares the reagents at the scene, which is inconvenient and time consuming and likely not worth the effort. Immunochromatographic cards are available for alpha-amylase, similar to those for blood and semen, and can identify whether an unknown stain contains salivary-type alpha amylase.[3] Whether to use these tests at scenes is a decision that requires careful evaluation. The decision concerns whether testing on-scene to identify saliva is important enough for the specific investigation or to protect the evidence for down-stream laboratory analysis. An example of the RSID immunochromatographic card to identify alpha amylase is shown in Figure 7.2.[4] In this test, the researchers analyzed ferret saliva and human saliva to prove there was no cross reaction.

Figure 7.2: RSID Chromatographic Card for Saliva

Like semen testing, investigators should have a rationale for testing saliva at the scene versus collecting the evidence and submitting it to the laboratory. In fact, the real question should be: Is on-scene saliva testing ever necessary?

There might be instances where the presence of saliva will have scene-specific reconstructive value. For example, if the ALS fluorescent-positive area on a victim's shirt or blouse is saliva, its location and pattern may suggest it came from an assailant instead of the victim. Such testing can be important for the scene investigation if it provides immediate investigative information that cannot wait. The team leader makes that decision. Finding a fluorescent stain on the wall might have investigative and reconstructive value, if the stain is saliva and it tells the investigator, based on the stain's pattern, that someone pressed a face against the wall. Perhaps it was the assailant's. If the investigators perceive that there is no immediate obvious value to the stain, it might never be collected, which would be a mistake. The primary question remains, however. How important is finding saliva in the overall investigative mission? Sometimes that question cannot be answered until later in the investigation. In other words, it is a mistake to forego collecting any biological evidence.

Collecting and Packaging Saliva Evidence

Collecting and packaging saliva evidence is exactly the same as for semen evidence.

Urine

It is not uncommon for a perpetrator to urinate at the scene, either on the floor or in a toilet, and finding it is not a problem because of its characteristic odor. Once dried, it fluoresces weakly under the ALS or under UV light, giving various colors. An immunochromatographic card has been developed to identify urine at the scene, which works well with stains on fabric but is less so with blood- and urine-mixed stains.[5] Until the RSID™-urine immunochromatographic card, there were no reliable on-scene test techniques for identifying urine, even presumptively, except for odor, so there was no chance of ruining the evidence before transmitting it to a forensic laboratory. Perpetrators do use toilets, so it is important to collect toilet contents, if there is a suggestion that urine is present. Since urine contains cellular material, the forensic laboratory needs to have a sufficient amount of it to obtain a DNA profile. Outdoor scenes should be searched thoroughly because it is not unheard of to find urine in snow.

Collecting and Packaging Urine Evidence

Collecting and packaging urine depends on how it manifests itself at the scene. If removed from the toilet, there will be a substantial volume to collect and package. If toilet contents are collected it should be transported immediately to the forensic laboratory. This is often impossible, however, given the constraints of an investigation. The problem is that the urethral epithelial cells should not remain in the urine's wet, acidic environment for extended periods.[6] The reason is that it has a deleterious effect on the DNA. If the urine contents cannot be transported immediately, the urine contents should be frozen as soon as possible or at least put on ice. Finding ice at convenience stores is not difficult or expensive. It then is the laboratory's job to determine how to extract the DNA.

If the urine is wet and in a puddle, say, on the floor, it can be collected into a container, such as described for liquid semen or absorbed onto an absorbent material, such as a sponge, a towel, a filter, or bench paper, and allowed to dry. Once dry, the DNA is more stable than if the urine remains wet. Sometimes urine is found on clothing that is either wet or already dry. If wet or damp, dry the evidence as soon as possible, preferably at the scene. Once dry, the DNA should be stable, certainly for hours until it can be taken to the forensic laboratory.

Feces

Human metabolism results in a waste product known as feces, which has been found at scenes of crimes, often in piles. Perpetrators defecate at scenes, so searching for their feces at the scene is an endeavor with important identifying implications. Locating it is not usually difficult, as its odor and characteristic appearance are fairly diagnostic and overwhelming and quite obvious. There are instances, however, where dried, brown swipes may be present that do not have the characteristic fecal odor, as drying will mute it. The easiest way to determine whether a dried, brown stain is feces is to swab a small amount onto a wet cotton swab and then smell it.

Collecting and Packaging Feces Evidence

Like its biological cousins, the components of feces can have important investigative information, the most important being DNA. Collecting and packaging wet feces is a simple matter of scooping it up, placing it into a casserole-like dish, and sealing it. If the evidence cannot be transported to the laboratory immediately, it should be frozen or at least put on ice. Keeping the feces cold is important because it contains destructive enzymes that can destroy the DNA. Feces can have important forensic value.

Vomit

While not one of the more common of the commonly occurring types of biological evidence, it is certainly found at scenes of crimes. Vomit can be important for the same reasons that feces are important: it contains cellular material that has DNA and it has foodstuffs that can tell something about the immediate eating habits of the person who vomited. Finding vomit at scenes is usually not difficult because the odor is so distinctive. Dried vomit stains have an odor, and like feces, dissolving a small amount in water and boiling it releases the odor. There are enzymatic tests for rennin, an enzyme present in vomit that can give more confidence that an unknown stain is vomit, but the odor test is sufficient for investigative purposes. The laboratory will do the appropriate tests, which will most likely be to extract the DNA.

Collecting and Packaging Vomit Evidence

The rule for collecting, packaging, and preserving vomit is the same as for feces and urine evidence. Like urine and feces, the acidic environment of vomit can be detrimental to the integrity of DNA, so collecting it and drying it or freezing it as soon as possible can be critical.

Hair

Although biological in origin, hair is almost ubiquitous. Nevertheless, finding probative hair evidence can be crucial in the final adjudication of a case. Hair grows from hair follicles, which means DNA is present. Although the hair has both nuclear and mitochondrial DNA (mtDNA), the former is found mostly in the hair root and only tiny amounts are present in the shaft. The shaft, however, is an ample source of mtDNA. Unfortunately, mtDNA is not unique enough to provide the investigation with a unique identification.

Understanding the structure of hair and how that can help determine which type of DNA testing is most appropriate for the found hair is important. It is also important to understand the meaning of hair found at the scene. Hair clutched in the hand of a dead victim suggests hair pulled from an assailant during a struggle. While collecting this hair might be the responsibility of the medical examiner, it is critical to ensure that the hair is collected and preserved for DNA analysis. Finding probative hair evidence requires logic and the appropriate use of technology and collection techniques. Certainly, a flashlight is appropriate, as is an ALS. The technique is the same as for all trace evidence; hold the light source at an oblique angle and search only those locations that make sense. An example is a homicide scene, and depending on how the homicide occurred, the deceased's body and its immediate vicinity should have the hair of the assailant present, if a struggle took place there. If the combatants fell onto furniture, that too, would be a logical place to search for probative hair evidence.

Collecting and Packaging Hair Evidence

There are three common methods used to collect hair evidence.

1. The hunt and peck (picking) method using tweezers to lift hair and placing it into an appropriate container (envelope).
2. Taping to lift the hair onto the sticky side of tape.
3. Vacuuming.

Fingerprint: Skin Residue

Crime scene investigators do not usually categorize fingerprint residue as a type of biological evidence. The reason is that the uniqueness of the friction ridge detail present on fingers, palms, and the soles of the feet had always been more important. That was before collecting DNA became important. Fingerprints contain biological material in two forms: the emulsion and the cellular content of the finger's epithelial cells. When a print is left on a surface, a certain amount of cellular material remains with the print residue. The number of epithelial cells deposited depends on factors that include the following:

- Time since last washing.
- Tendency of the individual to shed cells, such as whether the individual is a shedder.
- Mechanism by which the print was deposited. That is, was it rubbed onto the surface or was it gently placed?

Each cell has approximately 6 picograms (pg)* of nuclear DNA in its nucleus. While it is possible to obtain a DNA profile from a single cell, a form of forensic DNA testing called low copy number (LCN) testing usually requires approximately 22–25 pg (approximately four cells) of template DNA per amplification to obtain a useable profile. This is not a lot of cells, but preliminary experiments suggest that perhaps a maximum of 20 percent of useable fingerprints have sufficient DNA to obtain a nuclear DNA profile. Importantly, skin residue can also be transferred to a surface by touching. Consider the burglar who is looking into a residence and places his head against the window in order to better see. The forehead is a particularly good source of cellular material, and the residue on the window should be a decent source of DNA. A bare arm swiped across a wall or onto a table after someone falls onto it can also be a source of skin residue and hence DNA. Logically, understanding how the crime took place is crucial for determining whether skin residue will be an important source of biological evidence and thus play a critical role in the investigation.

Collecting and Packaging Skin Residue

For prints with useable friction ridge detail, the procedures currently used to collect fingerprints should be amenable to collecting a print's adhering cellular content. It is known that quantitative amounts of DNA are not collected using any of the traditional fingerprint collection methods: print lifting tape or casting with silicone casting material such as Mikrosil™ or with rubber-backed gel lifters.[7] Studies have shown that swabbing will lift the cells and that DNA profiles can be obtained from the swabs. For smudged fingerprints and other skin prints, finding them is the first issue for the scene investigator. Generally, powder dusting or an ALS might be the best way to find these prints. Once located, the smudged, powdered print can be swabbed and preserved by putting the swab into a swab-collection box of the type used for collecting vaginal swabs in rape cases. The boxed swab should be placed into a larger paper container. As for any biological evidence, no plastic containers should be used.

*One picogram is equal to one trillionth of a gram (10^{-12} g).

Sloughed-off Cells

This refers to our human penchant to continually shed cells, more commonly referred to as dandruff. Everyone sheds cells, and in the heat of a struggle, more cells should be shed than is normal. This is an elusive category of biological evidence for which no on-scene technology yet exists, so one might consider it an impossible mission. But this is most likely a prevalent category of physical evidence because it is ubiquitous where there are people. If located and collected, these cells could be an important source of DNA.

Collecting and Packaging Sloughed-off Cell Evidence

How would we find sloughed-off cells at the scene? Although no dedicated research exists, there are possible choices.

- Tape lift as though collecting trace evidence. Logic should lead to the appropriate areas to find this evidence.
- Fingerprint lift tape. This is an inefficient method for collecting DNA from fingerprint residue.[8] Swabbing the remaining print residue after lifting will capture the print residue and the cellular material left behind.
- Gellifter to lift the fingerprint. As with fingerprint lift tape, swabbing after gellifting captures the DNA left behind.
- For smudged prints, swabbing is the preferred method.

Not-So-Common Biological Evidence

Bacteria, Spores, and Viruses

In a world concerned with weapons of mass destruction, this is a particularly relevant topic. After the 2001 attacks on the World Trade Center and the Pentagon, packages containing anthrax spores were sent in the United States mail to Florida, New York, and Washington, D.C. The possibility of finding a suspicious white powder containing biological material (spores) at crime scenes is apparently real, which presents an insidious threat. The danger exists not only for those conducting the investigation but also the outside world if the material is not handled properly.

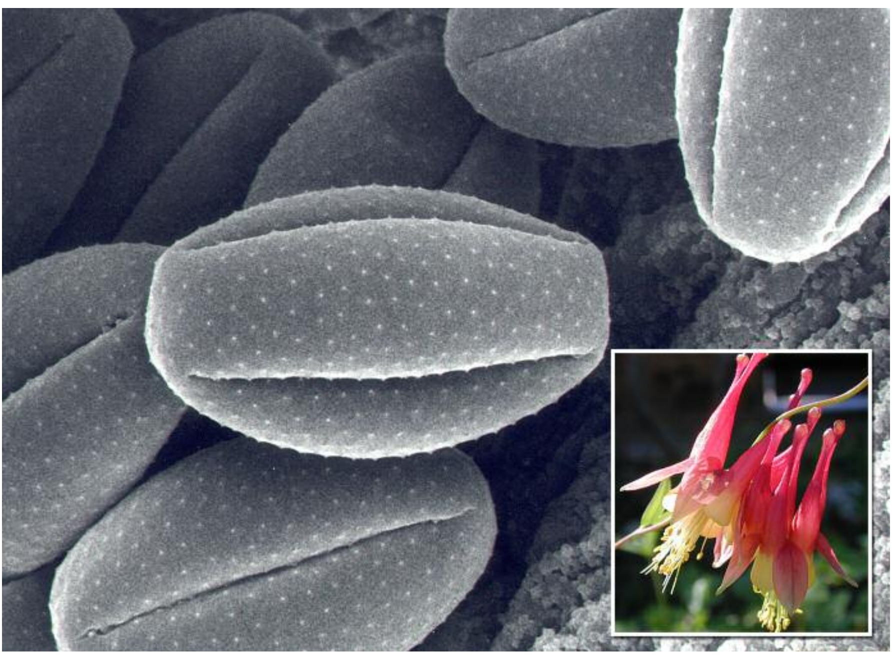
Plant Material

Four categories of not-so-commonly occurring biological evidence includes bacteria, plant material, pollen, and viruses. Actually, each is extremely common. Utilizing them for forensic applications is not so common, however.

Plant material has DNA, and a plant DNA profile can be determined much as for human DNA. Collecting and packaging plant material is done like any biological evidence. Finding probative plant material is the problem. Sometimes plant material will be found associated with tire tracks or shoeprints, which can be removed with tweezers and put into an appropriate container—a coin or glassine envelope—and labeled appropriately.

Forensic palynologists study pollen, which is a source of plant material that is small and hard to detect and is on all surfaces. In different times during a season, depending on location, it is easy to see and pollen grains are seemingly everywhere. Under these circumstances, these have little evidentiary value because everything has them. Pollen is useful as evidence when it is found associated with something at the scene that had been collected for another purpose (for example, a shirt from the deceased where pollen grains were transferred during the commission of a crime, or the sole of a shoe from someone who came from another country and brought the pollen with her).

Pollen reveals where a person or object has been because regions of the world have a distinctive collection of pollen species. It can even reveal the season when a particular object picked up the pollen. There are no standardized methods for collecting pollen, but the techniques used by investigators in the Amerithrax investigation should be considered. Taping or gel lifting techniques used to collect trace evidence should also be successful.



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Pollen as Evidence

A scanning electron microscopy image of the distinctive shape and size of pollen grains from *Aquilegia candanesis* (the Eastern or wild red columbine) is shown with an inset picture of the flower. It is native to the United States. Pollen similar to this was found embedded in a shirt discarded by the perpetrator of a murder in western Texas. While not the primary evidence that led to the murderer's conviction, the pollen did link his presence to the location of the crime.

Condom Evidence

In an age filled with the fear of contracting diseases such as AIDS and sexually transmitted diseases, individuals, as opposed to married couples, more often than not practice safe sex. Even sexual assault assailants wear them, probably not from the fear of contracting a disease but more likely to avoid leaving DNA evidence. When this happens, the value of the semen evidence and the victim's vaginal secretions or saliva on the assailant's penis are lost to the investigation. While the important DNA may be gone, condoms leave trace evidence that can still help the investigation. By analyzing each trace present in sexual assault evidence, the criminalist can construct a profile of a condom by identifying the particulates, lubricant, and spermicide present from other evidence found at the scene or at the hospital.[9]

Certainly, condom trace evidence does not have the perpetrator-ID capability of a DNA profile, but it can substantiate a victim's allegation that a sexual assault took place by proving evidence of penetration and thus of the crime. It can also help identify a serial rapist by linking common condom types. For these reasons, finding, packaging, and preserving condom trace evidence at sexual assault scenes is an important endeavor.

Collecting and Packaging Condom Evidence

- Wear powder-free gloves to protect against blood-borne pathogen infection and to avoid leaving particulates similar to those used by some condom brands.
- Package condom evidence in a breathable box or envelope. Dry wet semen before packaging.
- Package investigator's evidence collecting gloves separately and submit them with the evidence so that the forensic laboratory can verify that the gloves did not leave behind any particulates.
- Locate used condom and foil packaging. DNA from the victim on the outside proves that the condom was used with her and seminal fluid from the assailant on the inside will be the best evidence against a suspect.
- Save empty condom packets for fingerprint analysis.
- Wipe the inside of the condom package with a clean cotton swab that will become the standard for comparison with traces recovered from the victim and the suspect. The inside of an empty condom package should not contain fingerprints but might contain lubricant, spermicide, and particulate residues.

FOR GREATER UNDERSTANDING

Questions

1. What is the forensic value of saliva as an investigative biological material?
2. Is saliva more or less visible when seen using the ALS?
3. Why is it important to keep urine and feces evidence frozen?
4. Why is skin evidence important?
5. List three types of evidence left behind by condoms.
6. List the six guidelines for collecting and packaging condom evidence.

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Li, Richard. *Forensic Biology: Identification and DNA Analysis of Biological Evidence*. Boca Raton, FL: CRC Press, 2008.

Lecture 7 Notes

1. Gumucio, Deborah L., Karin Wiebauer, Robert M. Caldwell, Linda C. Samuelson, and Miriam H. Meisler. "Concerted Evolution of Human Amylase Genes." *Molecular and Cellular Biology*. 8(3): 1197–1205, 1988.
2. The Phadebas® website information on forensic saliva test products. — http://www.phadebas.com/products/forensic_saliva_test_products. Accessed 2/4/11.
3. RSID. Developmental Validation Studies of RSID™–Saliva Lateral Flow Immunochromatographic Test Strip for the Forensic Detection of Saliva. — http://www.ifi-test.com/pdf/Develp_Validation_Saliva.pdf. Accessed 2/4/11.
4. Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Chapter 13: "The Biological Crime Scene: It's Not Just About DNA." Boca Raton, FL: CRC Press, 2011.
5. RSID.
6. Castella, V., N. Dimo-Simonin, C. Brandt-Casadevall, N. Robinson, M. Saugy, F. Taroni, and P. Mangin. "Forensic Identification of Urine Samples: A Comparison Between Nuclear and Mitochondrial DNA Markers." *International Journal of Legal Medicine*. 120(2): 67–72, 2006.
7. Nabocny, Jennifer, and Robert C. Shaler. Unpublished results.
8. Ibid.
9. Blackledge, R.D., and L.R. Cabiness. "Examination for Petroleum Based Lubricants in Evidence from Rapes and Sodomies." *Journal of Forensic Science*. 28: 451–62, 1983.

Lecture 8

Bloodstain Pattern Analysis, Part One

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 14, "Introduction to Bloodstain Pattern Analysis (BPA): The Basics."

When blood leaves the human body, for whatever reason, it forms interpretable patterns. Often these alert investigators to nuances of what happened that would not otherwise be known.

This lecture is designed to introduce the concept of bloodstain pattern analysis to investigators so that they can recognize critical patterns when they encounter them at the scene and then document them properly in order not to lose their forensic value. The take-home lesson is that bloodstain patterns should never be left undocumented.

Blood evidence is multitasking because it can provide investigators with a wide range of investigative information. Some of its characteristics are considered below.

- Whose blood is at the scene.
- Distance from a target.
- Direction of travel.
- Energy of impact.
- Handedness.
- Relative position and movement of victim and assailant.
- Minimum number of blows.
- Sequence of events.

In our previous lectures, we discussed the important reasons for finding, collecting, and preserving blood evidence at the scene; certainly, DNA is one. Blood patterns can be equally compelling as physical evidence, if interpreted correctly. This means that blood evidence must never be overlooked or considered lightly during an investigation. Knowing whose blood made a particular pattern is important, but understanding how the pattern formed can also provide a critical piece of investigative information. Importantly, BPA can be done on-the-spot. For blood at the scene, the following should be considered:

- Whose blood it is.
- The circumstances of blood deposition.

The circumstance of blood deposition is important simply because bloodstain patterns can be more valuable for the investigation or to the medical examiner than knowing whose blood is present. Sometimes there is no question whose blood it is simply by understanding the pattern and its location. Like the scene investigation itself, BPA is deceptively easy. So, before considering the topic in more detail, it might be helpful to present, arguably, the historical presence and growth of BPA into the criminal justice system and specifically for law enforcement in the United States. This is a different discussion than the traditional historical account, where each investigator's contribution to the field is considered in some depth. These have been considered by others.[1, 2]

Historical Perspectives: BPA in the United States

The premise of bloodstain pattern analysts[3] is that when blood leaves the human body or a blood-covered object, it produces interpretable patterns, which occur in multiple scene types, especially at scenes of violent crimes and suicides. Interpreting these patterns reliably depends on the training and experience of the individual analyst. While not a new discipline, much like crime scene investigation in general, BPA has attracted individuals having diverse educational and professional backgrounds.[4] Such diversity seems shocking for a discipline supposedly having a basis in science. Much of forensics is an amalgamation or partnership of forensic scientists and law enforcement professionals participating cooperatively: one the scientist and the other the investigator. Crime scene investigation is likely the largest subdiscipline of forensics where science is practiced mostly by non-scientists and by some scientists, each often performing the same function. Certainly, BPA belongs in that same paradigm, which explains why lay investigators, who also perform science at the scene, quickly adopt BPA as an investigative specialty. Criminalists who participate in scene investigations also embrace BPA.

Arguably, BPA began in the United States at the University of California, Berkeley, with the work of Dr. Paul Kirk, a well-known and respected forensic scientist. Dr. Kirk was hired to investigate the 1950s murder of Dr. Sam Sheppard's wife. Sheppard was arrested and convicted of the crime, while claiming an intruder entered his house and murdered his wife. Dr. Kirk went to the scene and wrote a brief that described his analysis of bloodstain patterns. He concluded that there was evidence of someone else at the scene.[5] A book written by Sheppard's son and author Cynthia Cooper, *Mockery of Justice: The True Story of the Sheppard Murder Case*, produced DNA evidence suggesting that Kirk's interpretation was correct.[6] Kirk's work in the case has become a legendary example of BPA.

Law-enforcement agencies did not adopt BPA until after Herbert MacDonell published *Flight Characteristics and Bloodstain Patterns of Human Blood*[7] in 1971. Through workshops, MacDonell helped train law-enforcement officers in how to interpret bloodstain patterns. The result was a proliferation of individuals working BPA cases throughout the world. Importantly, the simplicity of these workshops spawned a cadre of self-styled experts who also offered workshops and published books and articles. MacDonell's workshops and those that followed were an easy-to-follow and lively format, which was and continues to be without rigor. Initially, there were no written examinations or other traditional grading mechanisms, which meant failing could not happen, and anyone who completed the workshop received a certificate of attendance, giving many a sense of expertise. In a sense, then, by requiring not much more other than completing a week-long course, attendees left with the feeling that BPA was simple enough to practice.

Recognizing the need for a formal organization around which the growing hoard of BPA analysts could communicate, MacDonell was instrumental in establishing the International Association of Bloodstain Pattern Analysts (IABPA) in 1983.[8] Ongoing workshops and a growing membership in the IABPA have resulted in the proliferation of lay investigators, many having dubious scientific and investigative credentials, who perform BPA in casework for both sides of the adversarial system. Their opinion testimony has played a critical role in determining innocence or guilt. The more recent publications are more scientific, as shown in a recent IABPA newsletter,[9] now a journal, *Journal of Bloodstain Pattern Analysis*.

The International Association of Investigators (IAI) initially considered BPA a subsection of its crime scene certification program. Now, the IAI certifies individuals in BPA who meet its requirements. Although the National Research Council's National Academy of Science's (NAS) report of 2009 questions the scientific basis of BPA, practitioners dispute this. The Scientific Working Group on Bloodstain Pattern Analysis (commonly known as SWGSTAIN) put together an extensive bibliography of relevant articles to counter possible legal challenges to BPA.[10] Even before the NAS report was published, however, scientists working in the Minnesota crime laboratory who have been active in bloodstain pattern research and education wrote that BPA is a scientific endeavor. The following was taken from the introduction of their article, which preempted the NAS report. They warned BPA analysts to move quickly to strengthen the discipline. Concerning the dynamics of how blood patterns form, they wrote the following:

> Relatively little, however, has been documented about the dynamics of the blood transfer event. BPA is a discipline that has relied heavily on the experience of the witness. *Closer scrutiny of the methods used in BPA will highlight the relative lack of underpinning scientific research and validation studies.*[11] (emphasis added)

SWGSTAIN's guidelines for practicing BPA produced a standard set of terminology that should eliminate the confusing terminology resulting from individuals who had published their own in the absence of a standard. Interestingly, the SWGSTAIN final version was not published until after publication of the NAS report in 2009. Before SWGSTAIN published its terminology, authors recognized how complicated BPA patterns could be and began introducing their own terminology, which made communicating confusing if not chaotic. SWGSTAIN's terminology is a welcome attempt at standardization. Importantly, it offers a terminologic playing field from which BPA analysts and novices can communicate.

Scientific Basis of Bloodstain Pattern Analysis

If BPA has a basis in science, then testimony at trial should be admitted into evidence as long as the testifying expert analyst meets appropriate standards and has the appropriate credentials. The BPA expert should understand the physics and mathematics relating to BPA, an understanding gained through education and experimentation while employing the principles of the relevant scientific disciplines: biochemistry, fluid mechanics (dynamics), physics, chemistry, ballistics, and mathematics. These disciplines form the scientific basis of BPA and, if BPA is a scientific discipline and not an art, their principles must explain why blood forms the patterns it does. If they cannot, then BPA does not have a basis in science and must be considered art.

Here, we are not implying that BPA has no scientific basis or that the opinions rendered in court are incorrect. The scientific basis, probably solid, must yet be proven: SWGSTAIN provides references designed to document the scientific basis of BPA.[12] The following discussion is designed as an overview of the disciplines relevant to BPA.

Biochemistry

To address the topic properly, one must understand the nature of blood, which requires knowledge of biochemistry and physics. Blood is a tissue, a liquid/solid suspension of plasma and cells. The liquid fraction (plasma) is water-based, a complex mixture of dissolved proteins, salts, and other molecules. The solid fraction contains a variety of cell types, making blood a viscoelastic, non-Newtonian fluid. And understanding what happens to it after it leaves the human body, whether acted upon by a force or just passively dripping from an object, requires more than empirically observing how bloodstains form in a workshop setting or in the field.

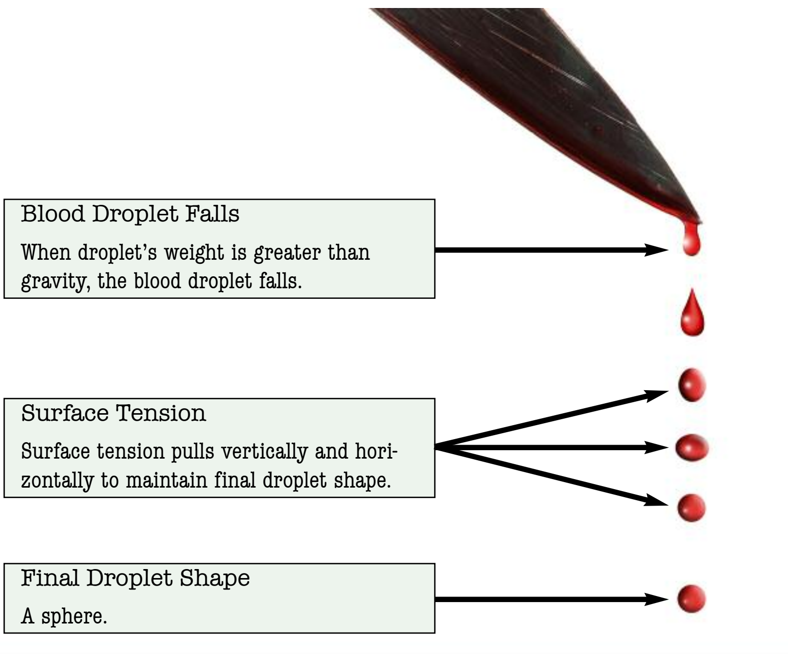
Physics

The laws of physics apply to blood droplets in flight. Fortunately, physics is a well-studied and documented discipline, and the direct application to blood-droplet formation and its flight characteristics should be understood. The problem for BPA is that these considerations have been taken for granted and, aside from empirical studies in workshop settings, few publications exist documenting that blood flight conforms to these laws. Certainly one would expect that it does. The following discussion concerns physics-related disciplines relevant to blood droplet movement.

Surface Tension

Blood plasma is composed of macromolecules, namely proteins, carbohydrates, water, dissolved salts, and other molecules. Its physical properties—viscosity and surface tension—are mainly determined by dissolved macromolecules in the blood's plasma. Surface tension forces blood droplets (or any liquid) to maintain its integral structure until acted on by a force greater than the force of surface tension. It is this force that creates blood spatter and thus the patterns observed at crime scenes. In the strictest sense, how the force is applied—its strength—determines the visual appearance of the resulting pattern. This is illustrated in Figure 8.1.

Figure 8.1 How Surface Tension Affects the Shape of Blood Droplets



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Fluid Mechanics (Dynamics)

Fluid mechanics is the study of fluids (liquids, gases, and plasmas) and the forces that act on them. Thus its laws define blood in motion, after being acted on by a force. Fluid mechanics, either fluid statics (fluids at rest) or fluid kinetics (fluids in motion), is a branch of continuum mechanics, which considers matter (including blood) as models in a continuum rather than as discrete atoms. Using fluid dynamic computations to describe blood in motion (for example, bloodstains formed from impact spatter) is particularly relevant. The bottom line is that every drop of blood (or perhaps pattern of blood) at the crime scene can and perhaps should be described mathematically. Some publications exist, but such a comprehensive study has not been done systematically.

Trajectory Analysis (Ballistics)

When a blood droplet leaves the human body under a force, it forms an arc, a path described mathematically. The blood droplet represents a projectile and its path is its trajectory. The shape of the arc depends on gravity, wind currents, temperature, humidity, and friction. Absent these external influences, the arc described by the blood droplet's path would be a parabola defined by a uniform, homogenous gravitational force field. In the real world such a singular effect is nonexistent. Air resistance (friction), drag, and nonuniform gravitational forces exert their influence on the path. So, the path the droplet takes is not a true parabola, its trajectory reflecting the influences of drag and gravity.

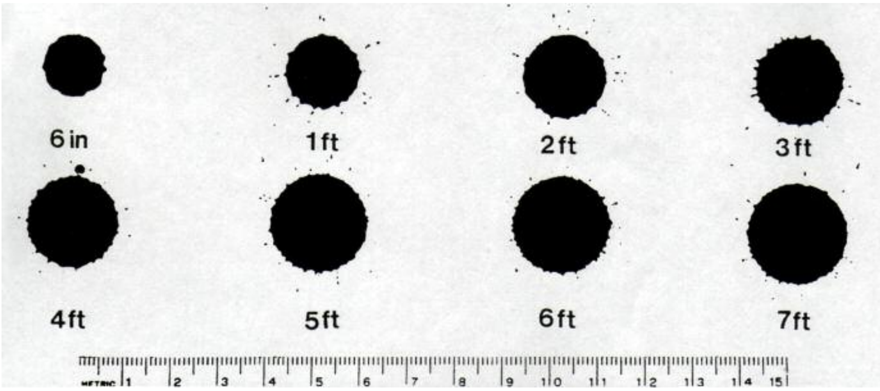
Gravitation (Gravity)

Gravity is one of the four fundamental interactions of nature (the four are strong and weak interactions, electromagnetism, and gravitation) where objects having mass attract one another. Described by the general theory of relativity, it is a consequence of the curvature of space-time that governs the motion of inertial objects and causes dispersed matter to coalesce, such as when the earth and other planets formed after the Big Bang. More common to us, it is the force that causes objects to fall to the ground when dropped. Gravity's influence on blood droplets was mentioned before as affecting a droplet's trajectory (path) because it defines the path an object (blood droplet) takes until it reaches its terminus. Thus gravity is responsible for the natural consequence of fluid flow. Its influence is starkly apparent in the visual pattern of spattered blood at scenes as well as pooling and flow.

Terminal Velocity

The concept of terminal velocity is also a concept of fluid dynamics. A blood droplet reaches its terminal velocity (settling velocity) when its acceleration due to the downward force of gravity equals the upward force of drag; its acceleration is zero. For bloodstains falling from identical heights and having a constant weight (volume), their terminal velocities will be identical. Similarly, when a blood droplet reaches its terminal velocity, the resulting stain, say on a hard, flat surface, will have a constant diameter, regardless of the height from which it falls. Generally, terminal velocity of a falling droplet occurs at approximately twenty feet, but empirical experiments in workshops show that bloodstain diameters change very little after falling approximately seven feet. This is illustrated in the photograph in Figure 8.2.[13] The cardboard onto which the droplets fell, although smooth, had some texture as evidenced by the formation of spines coming off the parent drop and satellite droplets surrounding the parent drop. The scalloping edge characteristics of the droplets are also indicative of a textured surface.

Figure 8.2: Height versus Droplet Stain Diameter



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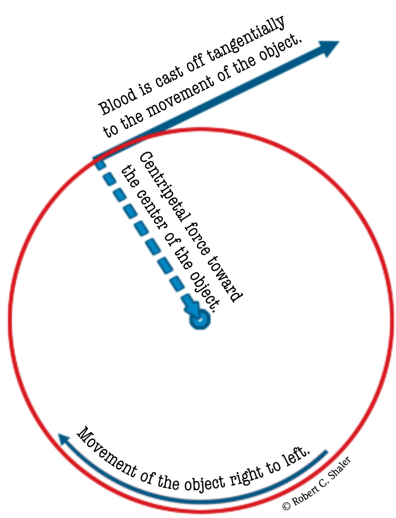
Single drops of blood falling onto smooth cardboard from various heights. Little change in diameter beyond seven feet.[14]

Centripetal Force

When wet blood is cast off a moving object (a weapon, hands, or what have you), only one force is at work, centripetal force, a force directed toward the center of the path of the moving object. When the adhesive forces holding the blood onto the object are greater than the centripetal force, the blood flies off the object tangentially in a straight line. The resulting impact site is a direct link to the location of the object at the precise moment the blood left the object, as illustrated in Figure 8.3.

Figure 8.3: Centripetal Force and Blood Cast Off from Bloody Object

- Centripetal force is directed toward the center of the path of the moving object.
- When adhesive forces holding blood onto the object overcome centripetal force, the blood will fly off the object in a tangentially straight line.
- The impact angle of the stain is a direct link to the location of the object at the exact time the blood left it.



FOR GREATER UNDERSTANDING

Questions

1. Blood is a multitasking category of physical evidence. List four types of information bloodstain evidence can provide investigators.
2. Why is understanding and interpreting bloodstain patterns often more important from a forensic perspective than knowing whose blood made the pattern?
3. What is SWGSTAIN? The IAI? The IABPA?
4. What is the importance of surface tension with respect to blood-droplet formation?
5. What role does trajectory analysis play in understanding the formation of bloodstain patterns at a crime scene?
6. What is terminal velocity? Why is understanding the concept of terminal velocity important in interpreting bloodstains at a crime scene?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Bevel, Tom, and Ross M. Gardner. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction*. 3rd ed. Boca Raton, FL: CRC Press, 2008.

Committee on Identifying the Needs of the Forensic Science Community. *Strengthening Forensic Science in the United States: A Path Forward*. Pp. 127–91. Washington, D.C.: National Research Council of the National Academies, 2009.

Cooper, Cynthia L., and Sam Reese Sheppard. *Mockery of Justice: The True Story of the Sheppard Murder Case*. Pp. 5–13. Boston, MA: Northeastern University Press, 1995.

Eckert, William G., and Stuart H. James, eds. *Interpretation of Bloodstain Evidence at Crime Scenes*. 2nd ed. Boca Raton, FL: CRC Press, 1999.

MacDonell, Herbert Leon. *Flight Characteristics and Bloodstain Patterns of Human Blood*. Washington, D.C.: National Institute of Law Enforcement and Criminal Justice, 1974 (1971).

Lecture 8 Notes

1. Bevel, Tom, and Ross M. Gardner. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction*. 3rd ed. Boca Raton, FL: CRC Press, 2008.
2. Eckert, William G., and Stuart H. James. *Interpretation of Bloodstain Evidence at Crime Scenes*. 2nd ed. Boca Raton, FL: CRC Press, 1999.
3. Bevel, Tom, and Ross M. Gardner.
4. Committee on Identifying the Needs of the Forensic Science Community. *Strengthening Forensic Science in the United States: A Path Forward*. Pp. 127–91. Washington, D.C.: National Research Council of the National Academies, 2009.
5. *State of Ohio* vs. *Samuel H. Sheppard*. Affidavit of Paul Leland Kirk. Court of Common Pleas, Criminal Branch. Cuyahoga County, OH, no. 64571. P. 1. 1955.
6. Cooper, Cynthia L., and Sam Reese Sheppard. *Mockery of Justice: The True Story of the Sheppard Murder Case*. Pp. 5–13. Boston, MA: Northeastern University Press, 1995.
7. MacDonell, Herbert L., and L. Bialousz. 1971. *Flight Characteristics and Bloodstain Patterns of Human Blood*. Law Enforcement Assistance Administration, Washington, D.C.
8. International Association of Bloodstain Pattern Analysts (IABPA) website. SWGSTAIN Research Subcommittee. "Bibliography Project." April 2009. Available at http://www.iabpa.org/SWGSTAINReferenceListbyGroupApril2009.pdf. Accessed 2/5/11.
9. Yamashita, Brian. "Physics and Mathematics in Bloodstain Pattern Analysis." Third European IABPA Training Conference. Lisbon, Portugal. Newsletter, May 19–21, 2010.
10. International Association of Bloodstain Pattern Analysts (IABPA) website. SWGSTAIN Research Subcommittee. "Bibliography Project." April 2009. Available at http://www.iabpa.org/SWGSTAINReferenceListbyGroupApril2009.pdf. Accessed 2/5/11.
11. Laber, Terry, B. Epstein, and M.C. Taylor. "High Speed Digital Analysis of Bloodstain Pattern Formation from Common Bloodletting Mechanisms." Project Report. Midwest Forensic Resource Center (MFRC) Project No. 06-S-02. IABPA Newsletter, June 2008.
12. International Association of Bloodstain Pattern Analysts (IABPA) website.
13. Eckert, William G., and Stuart H. James.
14. Ibid.

Lecture 9

Bloodstain Pattern Analysis, Part Two

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 14, "Introduction to Bloodstain Pattern Analysis (BPA): The Basics."

Reconstructing the sequence of events at bloodletting scenes requires an understanding of the fundamental principles of bloodstain pattern formation, which means understanding what happens to blood in flight.

Fundamental Principles of Bloodstain Analysis

Empirical work has identified areas of bloodstain pattern analysis that many consider fundamental. These include the direction of movement of a bloodstain and the angle of impact; the angle at which blood droplets strike a surface.

Defining the Direction of Blood Travel

Shape of Blood Droplets After Striking Surfaces

Figure 9.5 illustrates what bloodstains should look like after striking a sloped surface.[1] As the impact angle becomes more and more acute, the stain elongates, eventually forming a tail, see bottom right example, which points toward the direction the blood droplet was traveling.

Blood or Drip Trails

According to the SWGSTAIN terminology above, a drip trail is a "bloodstain pattern resulting from the movement of a source of drip stains between two points." When blood drips from an object in motion, the resulting droplet shapes can range from nearly circular (falling nearly perpendicular to the surface) to elongated (hitting the surface at an angle). However, for blood dripping from slowly moving objects, such as from someone walking with a bleeding wound, the droplets can be nearly circular, such that they mimic droplets falling vertically from a height. An example of a drip trail is shown in Figure 9.1. Arrows show three droplets in the trail.

Figure 9.1: Drip Trail

Determining the direction of trails requires closely examining the droplet edge characteristics, and this very much depends on the texture of the interacting surface—how smooth it is. Generally, the edge characteristics of droplets in motion point in the direction the droplet is traveling, which should be the direction the person is moving. And depending on the texture of the interacting surface, the leading edge (the edge in the direction of travel) will be more or less uneven, that is, it can have scalloping, spines, and satellite stains. Analyzing several stains in the trail is the proper technique for determining direction of travel of a blood trail. Using one droplet can lead to interpretative errors.

Shape and Size of Bloodstains

The shape of bloodstains is dependent not only on the angle at which it impacts the surface but also on the characteristics of the surface it impacts: texture, absorptive properties, and thickness. In Figure 9.2, the photographs show blood droplet stains on T-shirt material (top photograph) and on a thick, absorptive cotton towel (bottom photograph). Generally, the rougher the surface the greater its texture and the more disrupted the resulting droplet stain will appear. In the upper stain, T-shirt material, the edge of the stain is irregular, spines (projections) are apparent and so is a satellite droplet stain, all misshapen due to the texture of the material. The bottom stain is a droplet of the same volume dropped from the same height as that on the T-shirt material. This is a highly absorptive, thick cotton towel, and the droplet shape is different from that on the T-shirt material. The diameter of a droplet stain depends not only on the volume of the droplet but also on the absorptive properties of the surface. If the surface absorbs liquids readily and is thick enough, the stain's appearance tends to be compact, reflecting the ability of the surface to absorb the blood quickly and deeply into its matrix.

Figure 9.2: Effect of Surface Absorption on Shape and Size of Bloodstains

Shape vs. Target Surface

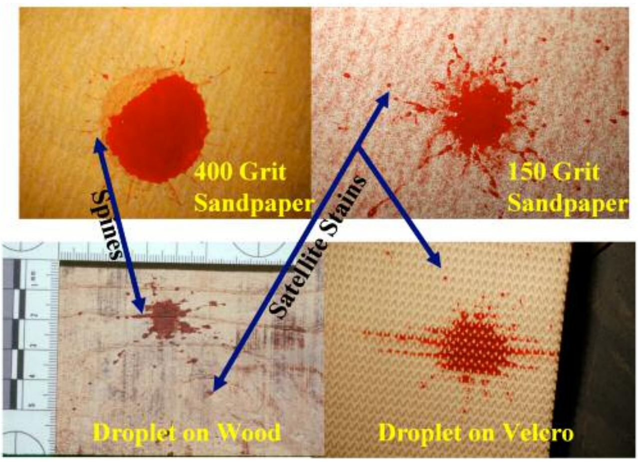
- Texture (rough or smooth)
  - –Affects shape of droplet
  - –Collisions with surfaces that are not flat

Size

- Distance fallen
  - –Little change in diameter beyond 8 feet
- Absorptivity/Porosity
  - –The more absorptive, the better spreading of a droplet onto a surface
- Thickness
  - –Thick, absorptive surface pulls droplet into matrix and keeps from spreading

In Figure 9.3, the photographs illustrate how the texture of the surface affects the appearance of the resulting stain, minus the absorptive effect discussed above. All four photographs are of blood droplets dropping onto nonporous surfaces. The top two photographs illustrate how sandpaper grit (roughness)—400 (smoother) and 150 (rougher)—affects the appearance of the resulting stain. The general rule of thumb is that the rougher the surface, the more disrupted the resulting stain. The lower left photograph shows a stain produced from a droplet impacting a piece of wood. The lower right photograph shows what happens to a droplet falling onto the hooked side of Velcro: the blood wicked along the hooks (right and left) giving an unusual stain with elongated spines. Satellite stains are also visible (arrow).

Figure 9.3: Effect of Surface Texture on the Shape of Bloodstains



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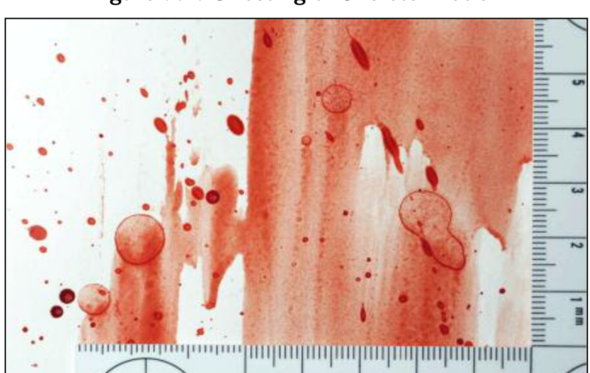
Perimeter Stain: Ghosting or Skeletonization

The drying of blood moves from the outside toward the inside. This happens because the outside edges lose water faster than the middle of the droplet, which is thicker. Therefore, the edges dry quicker. If something brushes across the drying droplet, the edges form an outline of the original droplet (see arrows in Figure 9.4).

Figure 9.4: Ghosting or Skeletonization

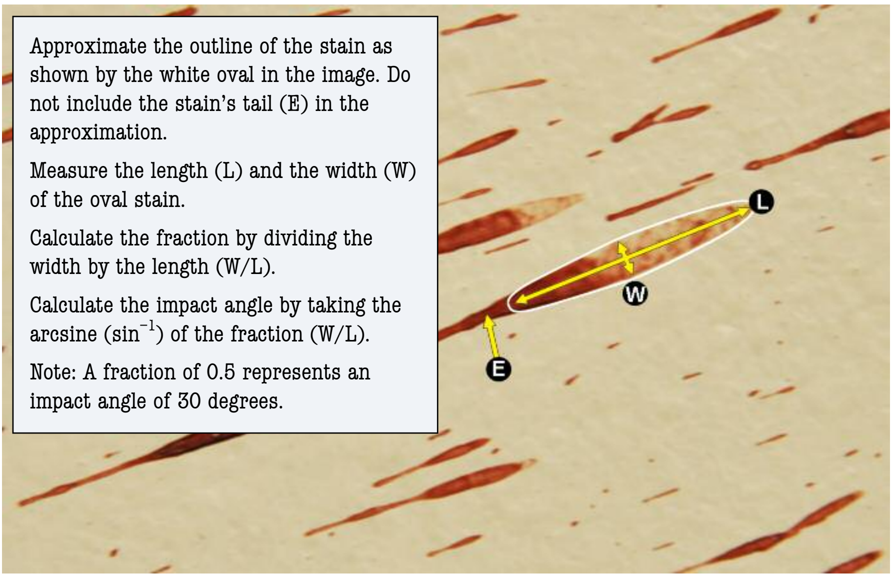


Photograph © Ralph R. Ristenbatt III. Used with permission.

Calculating the Angle of Impact

Understanding the mechanism of why blood forms elongated stains as the angle at which it strikes becomes increasingly small is critical for understanding how to determine the angle at which the blood impacted with the surface. The step-by-step procedure for measuring a stain prior to making the calculation is shown in Figure 9.5.

Figure 9.5: Calculating the Angle of Impact



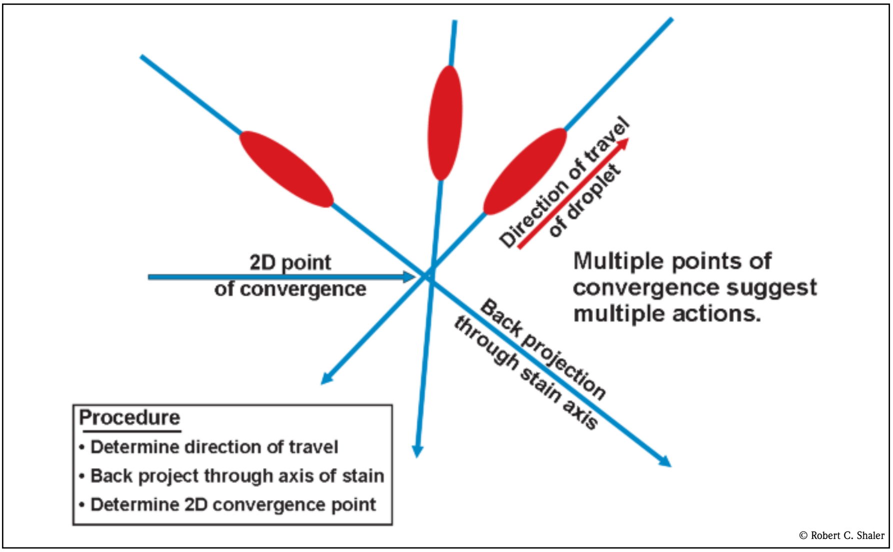
Error rates can be quite high and can range from 1 to 2 percent to over 20 percent, with an average of approximately 5 percent. Recent publications have targeted errors in calculating impact angles using more rigorous mathematical methods.[2, 3]

Determining the Origin of an Impact or Area of Convergence

The first step in determining the area of convergence of an impact that originated from a single source is to determine the point of convergence, the 2D location of an impact, e.g., blunt force trauma when someone is struck with an object. Importantly, for blood to be spattered, it must be present, which means that the first impact produces the blood without spatter. The back projection approach can help determine a possible minimum number of blows or impacts. Multiple points of convergence suggest multiple blows. This is also a mechanism for selecting the proper bloodstains from within a bloodstain impact spatter pattern to use for determining the 3D area of impact. Figure 9.6 illustrates the process.

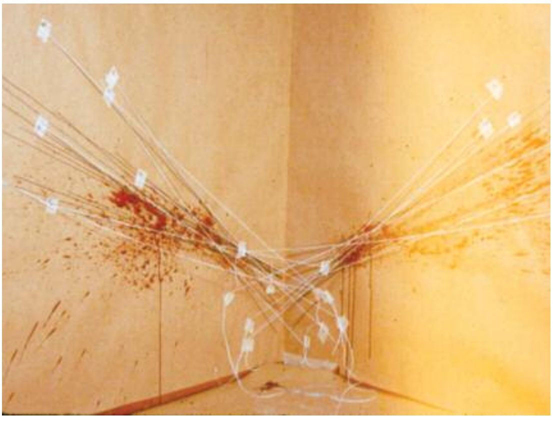
The spatial location of an impact that caused impact spatter pattern can be important in piecing together a possible sequence of events. Essentially, this is the third dimension of the 2D back projection method discussed above. It can be determined using 3D imaging techniques, such as 3D scene imaging systems and computer aided design (CAD) programs or software specifically designed for the application. It can also be approximated at the scene using what is known as the string method manually or by using lasers.

Figure 9.6: Back Projection Method for Point of Convergence



The string method is a manual procedure for approximating the area of origin resulting from an impact. Generally, several appropriate stains are selected (10 to 20) from within a bloodstain pattern; the best stains are identified using the 2D back projection. An example of the string method is shown in Figure 9.7, an experiment to re-create a stomping death. The impact angles were measured as described in Figure 9.6 and strings were run to the floor and anchored with tape at those angles. The area of impact is where the strings more or less converge.

Figure 9.7: Example of the String Method



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Castoff

When blood leaves a blood-covered object it can either drip passively or be propelled from it. In a forensic context, blood leaves a blood-covered object when the centripetal force acting on it overcomes the adhesive forces holding the blood onto the object, which is true whether the blood cast from the object occurs while the bloody object is being swung or if it comes to an abrupt halt (cessation castoff).

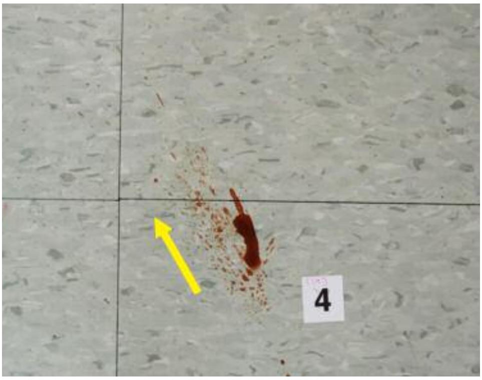
If blood is on a bloody knife and the knife is swung in an arc, blood will be propelled from (castoff) the knife in a path that is tangentially straight from that point and travel until it hits a surface. If blood hits the surface while still traveling in a straight line, the shape it takes will represent the angle of the impact, and trigonometric functions can be used to calculate its impact angle and also backtrack to the spatial location of where it left the bloody object. More than one droplet will usually leave the bloody object as it moves through its path, the preponderance of which will form a pattern characteristic of the bloody object.

Surface area of the object facing the impact surface is reflected in the width of the pattern produced. If a bloody hand is held open-faced to a wall, the individual fingers will cast off blood, making a pattern of a line of blood droplets from each finger.

The breadth of the castoff pattern generally reflects that of the blood-covered surface area of the object's surface facing the impact site. An edge of a knife blade can give a single line of castoff staining.

A unique type of cast off occurs when a bloody object comes to a rapid halt, which occurs when a blood-covered weapon strikes a wall, a person, or another object. In Figure 9.8, the cessation castoff happened when a bloody knife fell to the floor. The yellow arrow shows the direction of movement when the knife hit the floor.

Figure 9.8: Cessation Castoff



Bubble Stains

Bubble stains form when air is present in the droplet. An example or expectorated blood is shown in Figures 9.5 and 9.9. The stains have obvious air bubbles, expected in blood expectorated from the lungs or from the mouth.

Figure 9.9: Bubble Stain

Archiving Bloodstain Patterns

Scene investigators are not necessarily BPA analysts but they need to understand and recognize bloodstain patterns and then follow appropriate guidelines in order to properly preserve them. The first step is to examine the bloodstain pattern carefully to ascertain its overall characteristics. Then try to answer the following questions.

1. How much area does the pattern encompass?
2. Is the pattern a composite of multiple patterns?
3. How might this pattern have occurred?

An example of a complex bloodstain pattern is shown in Figure 9.10 before scales were in place. It is a midrange shot of the bed and wall behind the bed. The stains on the bed, those on the wall behind the bed, and those on the floor next to the bed were important. Not shown in the photograph are the cast-off stains: on the ceiling above the bed, on the wall to the left of the bed, and on the wall opposite the bed.

Figure 9.10: Midrange Photograph of Bloodstained Bed and Wall

Visually, there are multiple superimposed patterns that must be captured for a meaningful archive of these patterns. The photo can be broken down into its most visually apparent components; others are also present:

- Multiple impact spatters.
- Large swipe/wipe pattern on the wall behind the bed leading from just above the bed and flowing downward toward the floor.
- Smaller swipe patterns on the wall to the right of the main impact spatter.

Close-up photographs will provide additional detail (misting, for example), and capturing these patterns properly will require several photographs. The initial photographs are taken without scales and should be repeated with scales pasted on the wall. It is important to detail and preserve the overall size of the pattern as well as subpatterns within the whole.

Bloodstain Artifacts

Experienced investigators know that when they arrive at the scene it is no longer virginal. That is, it must be considered a scene that is not as it was when the crime took place. This is true for many reasons. Certainly blood evidence is not exempt from the ravages of evidence dynamics. Examples of things that happen to blood evidence range from cleanup activity to officials responding to the scene, to emergency medical personnel trying to save lives and common weather complications. Artifacts occur from people who work on the scene and animals or insects who dine or traipse through the scene.

Contamination and artifacts from insects dining on dried or wet blood at the scene should be expected. Such artifactual staining can be confusing and misinterpreted. Cockroaches and flies leave telltale marks. Investigative personnel can affect bloodstain evidence by altering blood present or creating new patterns during the investigation. Even blood landing on fabrics can create patterns that are not expected because of the differential absorption of blended material.

FOR GREATER UNDERSTANDING

Questions

1. What is the relationship between the shape of a dried bloodstain and its impact angle?
2. How does surface texture affect the shape of bloodstain droplets?
3. What is the impact angle?
4. How does the “point of convergence” differ from the “area of impact”?
5. What is meant by the term “area of impact”?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Bevel, Tom, and Ross M. Gardner. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction*. 3rd ed. Boca Raton, FL: CRC Press, 2008.

Committee on Identifying the Needs of the Forensic Science Community. *Strengthening Forensic Science in the United States: A Path Forward*. Pp. 127–91. Washington, D.C.: National Research Council of the National Academies, 2009.

Eckert, William G., and Stuart H. James, eds. *Interpretation of Bloodstain Evidence at Crime Scenes*. 2nd ed. Boca Raton, FL: CRC Press, 1999.

Gardner, Ross M., and Tom Griffin. “Foundations for the Discipline of Bloodstain Pattern Analysis: A Response to the Report by the National Academy of Sciences.” *Journal of Forensic Identification*. 60(4): 477–94, 2010.

MacDonell, Herbert Leon. *Flight Characteristics and Bloodstain Patterns of Human Blood*. Washington, D.C.: National Institute of Law Enforcement and Criminal Justice, 1974 (1971).

Lecture 9 Notes

1. Shaler, Robert C. “Chapter 14: Introduction to Bloodstain Pattern Analysis (BPA): The Basics.” *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.
2. Rowe, Walter F. “Errors in Determining the Point of Origin of Bloodstains.” *Forensic Science International*. 161; 47–51, 2006.
3. Willis, Cordelia, Anna K. Piranian, John R. Donaggio, and Robert J. Barnett. “Errors in the Estimation of the Distance of Fall and Angles of Impact Blood Drops.” Forensic Science International. 123; 1–4, 2001.

Lecture 10

Shooting Scenes, Part One

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 20, "Introducing Shooting Scene Investigations."

Unfortunately, shootings are all too common in our society. Understanding what happens to bullets when a weapon is fired and their relationship to Locard's Exchange Principle is an important step toward reconstructing these crimes.

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The classic shooting incident image is film noirish or gangster related: the Capone gang spraying bullets inside the SMC Cartage Company garage on Valentine's Day in 1929.[1] Modern society's images are more troubling: A college student shoots up a campus classroom killing multiple innocents,[2] the vice president of the United States accidentally shoots a lawyer in the face with a shotgun,[3] or an army officer murders his fellow soldiers at a military base in Texas.[4] In fact, shooting incidents make headlines almost daily. We classify shooting incidents into one of the following categories:

- Suicide
- Accidental discharge of a weapon—hunting incidents/stray bullets
- Homicide
- Drive-by shootings
- Terrorist activity
- Emotionally disturbed incidents

Understanding and reconstructing the shooting incidents means identifying, interpreting, and preserving all critical forensic evidence. Specific scene-dependent activities and considerations are required to ensure a comprehensive scene investigation and subsequent reconstruction. This means an understanding of how firearms work and how projectiles interact with targets, the ammunition employed and its chemistry, and determining bullet flight paths.

On-Scene Considerations and Activity

Investigators must thoroughly understand the principles of shooting scene incidents and have a thorough understanding of how to conduct a comprehensive and competent scene investigation. Certainly a prerequisite is reasoning appropriately and understanding how to employ the scientific method properly. The thought process should center on what happened and its implications. If a mark suggests a ricochet, identifying it as such is important and the relevant question would be, "What would I expect a ricochet mark to look like under these circumstances?" This is an experienced-based question, but knowing what to expect can lead to finding firearms-related evidence, such as an original impact site or defect, a bullet terminus, the bullet, or understanding the victim's wounds and/or holes in clothing. The thought process should also consider what physical evidence is known to the investigation (for example, damage to the recovered projectiles, wound characteristics, bullet hole/ricochet characteristics [size, chemistry, trace evidence] and how it relates to the overall scene characteristics). Some information might be in dispute, such as the specifics of the event, but this should not be the prime consideration, especially at first. The medical examiner will answer other shooting-related questions, such as distance from a wound based on stippling or fouling on a victim's skin. Certainly, the entire investigation should be based on employing the scientific method using appropriately validated scientific protocols and standards.[5]

Shooting scenes are unique in that they involve bullets, their marks, and recovery, but this should not interfere with or take precedence over the usual good crime scene investigative practice. The successful investigation of a shooting incident requires a diligent effort to obtain specific firearms-related information within the context of the usual practice of archiving, sketching, managing, and so on. An open-minded investigation is critical to ascertaining the basic truth of what happened and an objective gathering of critical facts. The following is an example of a not-all-inclusive list of information that should be obtained.[6]

- Number of individuals involved—shooters and nonshooters.
- Number of witnesses and their relative locations and sight lines.
- Lighting/weather conditions.
- Bullet/defect identification and chemical analysis.
- Bullet flight path angular component determinations.
- Muzzle-to-target distances, if necessary.
- Number of shooters.
- Identification of shooters.

- Position of shooters.
- Location and type of trace evidence.
- Collection of all firearms evidence.
- Artifacts created by EMTs, witnesses, investigators.
- Categorization of victims.
- Wounds—anatomical location, tracks, entrances and exits.
- Location and position of victims at the scene.
- Collection of fragile evidence.

Fragile Evidence

This is an important category of evidence that is present in all scenes, including shooting incidents. Particular to shooting scenes, however, is evidence unique to the discharge of a firearm. The following discussion details fragile evidence that might be found at shooting scenes.

Gunshot Residue (GSR)

Gunshot residue is composed of easily dislodged particles. Anything that might contain GSR must be located expeditiously, collected, and preserved properly. The list of places where GSR might be found depends on the specific investigation, but common places include the hands and clothing of victims and shooters, bullets, ricochet, defects, and bullet holes. When collecting evidence, such as clothing, packaging is critical. Generally, carefully folding clothing, much as for preserving bloodstain evidence, is important to avoid an inappropriate transfer of the GSR from one part of the clothing to another. It is also important to package each item separately. Protecting areas where GSR might have fallen or was deposited, such as pockets, arms, or where a shooter stood, is critical.[7]

Cartridge Cases

These are important because they can pinpoint the area from which a weapon was discharged (semiautomatics). They contain ejection marks, firing-pin marks, and other marks that have important comparative forensic value, which means protecting them from further damage (other than the marks made after ejection from the weapon) is important. In addition to the cartridge cases, the pattern they form after ejection from the weapon is a separate category of fragile evidence. These patterns must be archived photographically because cartridge cases are easily moved (kicked).[8]

The Usual Fragile Evidence

In addition to shooting-scene-specific fragile evidence, the usual fragile evidence associated with all scenes may also be important. These include footprints, tire tracks, fingerprints, and other typical crime scene evidence.

Bullets

Bullets will be discussed in more detail later, but the following underscores information available to the investigation from bullets.

- Deformation to ascertain angle of impact and strike surface characteristics.
- Fragmentation and their location.
- Rifling and twist to help identify specific weapons.
- Number of lands and grooves visible.
- Adherent trace evidence.
- Blood.

Bullet and Projectile Marks and Holes

Bullet impact marks and bullet holes can have fragile trace evidence critical to identifying what a bullet struck on its path to its terminus. While there is minimal risk of the bullets being ruined like footwear impressions, the marks they produce has microscene elements that require serious consideration concerning their preservation.[9] Blindly performing tests on a bullet hole can ruin the trace evidence present, which means that the sequence of testing must be considered carefully, with chemical analysis being last.

- Document the defect photographically.
- Preserve the evidence present. A way to do this is to tape lift the trace evidence present. Another approach could be to cast the defect/hole using silicone casting material that can capture the trace evidence and also mold the defect.

The following is a general checklist of evidence that could be obtained:[10]

- Categorize all bullets from all weapons, at the scene or from recovered weapons.
- Determine the number of missing bullets from all weapons.
- Identify the number of cartridge casings recovered versus the number that should have been recovered.
- Locate and count the number of identifiable bullet holes (entry versus exit), ricochet marks, or other defects at the scene as well as those in victims (from autopsy X-rays).
- Locate and inventory all bullet strikes and deflections.
- Identify the number and types of wounds.
- Obtain witness accounts of shots fired.

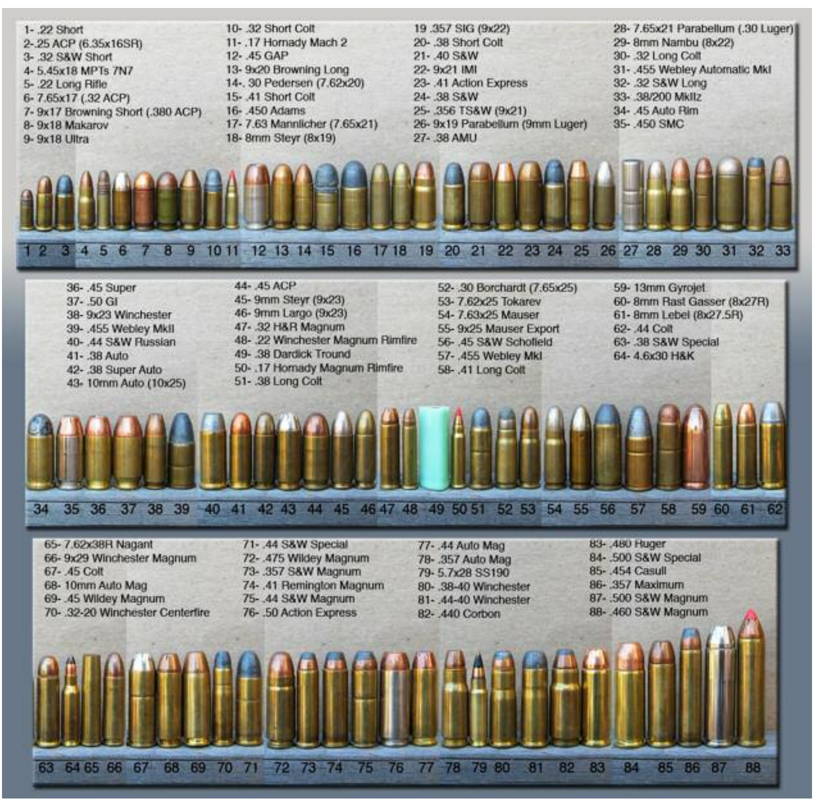
The presence of firearms evidence creates a new set of investigative challenges. The usual sexual assault requires a search for biological and trace evidence. However, if that case also involves a shooting, the scene's complexity ramps up several notches. If it also involves a vehicle, the scene complexity increases.

Basic Facts and Definitions

As with any new topic, forensic ballistics has its own language, and being familiar with it is important in order to communicate effectively. The following discussion introduces the nuances of shooting scenes, presenting them as both different and the same as other scene types. It is important to introduce the language of shooting scene investigations.

Ammunition

While scene investigators need not be ballistics experts to conduct a shooting investigation, they should be familiar with the forensic aspects of ammunition and the information it has to offer an investigation. From a forensic perspective, small arms ammunition consists of four elements: cartridge case, primer, propellant, and bullet. Essentially, there are three common types of ammunition that are manufactured: rimfire, center fire, and caseless.



A sampling of eighty-eight cartridges from the vast amount of ammunition available for handguns in the world today.

Shotgun shootings are also common and, like other types of ammunition, this ammunition has its own language. The bore or gauge, such as 0.410 inches, refers to the number of lead balls of the same diameter as the inside of the barrel that weighs one pound. Thus, a 12-gauge shotgun has a barrel of 0.729 inches and twelve round balls 0.729 inches in diameter that weigh one pound. Unlike rifled weapons, shotguns have a smooth barrel that fires pellets, a single ball, or dust shot.[11] Shotgun pellets are traditionally composed of lead and a small amount of antimony. Other materials also include soft steel with a copper coating, and bismuth alloyed with iron and tungsten. The single projectiles used in shotguns are called slugs, which can be round balls, also known as pumpkin shot. The type of shot depends on its shape.[12]

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A 12-gauge shotgun shell with a slug projectile.

Primer Compounds and Their Composition

Priming compounds are a shock-sensitive mixture of chemicals that explode when struck by an object such as a firing pin. The debris resulting from that explosion is what is known as primer powder or gunshot residue (GSR).

Lead-based Primers

Until 2000, the most common components of priming compounds were lead based. Typically, they included explosive ingredients (lead styphenate and tetrazine), an oxidizer (barium nitrate), and a fuel to promote burning (antimony sulfide). Powdered glass was added to increase friction and to assist in the detonation. Aluminum and magnesium were added for high-powered magnum pistols and rifles.

Lead-free and Nontoxic Primers

There has been a move to replace the poisonous lead in primers with lead-free equivalents, with the development of explosive chemicals such as dinitrodihydroydiazoenzene salt (diazinate), dinitrobenzofuroxan salts, potassium dinitrobenzofuroxan, perchorate or nitrate salts, diazo, trizole, and tetrazole compounds, and others. New oxidizers include zinc oxide, potassium nitrate, strontium nitrate, and zinc peroxide. The fuel components might include boron, metallic powders, carbon, silicon, and metal sulfides.

Forensic Ballistics

There are four categories of ballistics: internal, intermediate, exterior, and terminal. Anyone working shooting scenes should understand the differences among them. The following short discussion introduces the concepts of most importance to the crime scene investigator.[13]

Internal (Interior) Ballistics

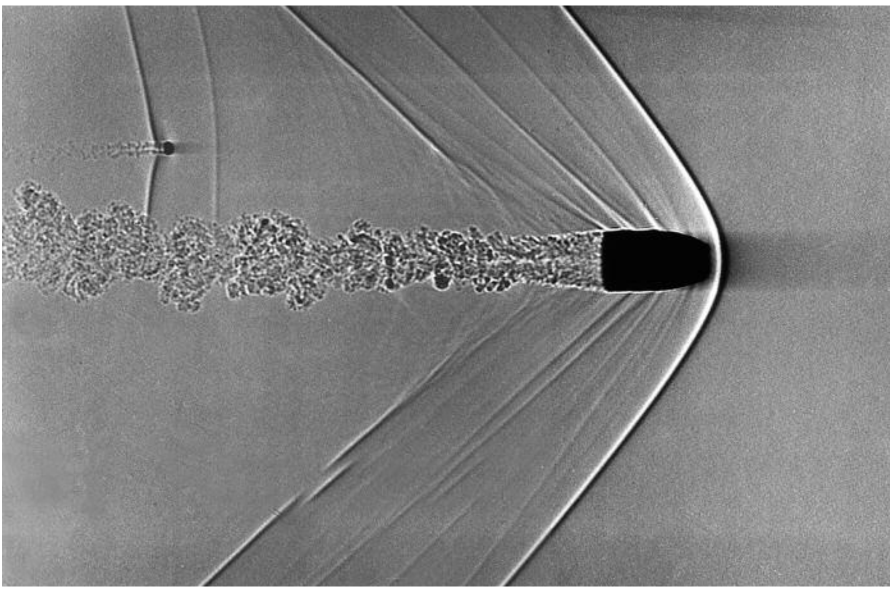
This is the study of what happens in the barrel of a weapon, specifically to what happens when the firing pin strikes the primer to when the bullet or projectile exits the barrel of the weapon. A number of topics interest individuals who study this area of ballistics, including primer ignition, barrel pressures, velocity, time the bullet remains in the barrel, and recoil.

External Ballistics

This is the study of bullet flight after it leaves the muzzle, also known as the bullet path or, incorrectly, the trajectory. For most shootings, distances are short, which means the maximum range of the firearm is not a serious consideration. However, depending on the scene, long-distance shots could become a part of the investigation. In these instances, appropriate expertise should be sought. The subject is complex, involving calculations that include bullet shape, sectional density, atmospheric pressure, and possibly the rotation of the earth.[14]

Terminal Ballistics

This refers to what happens when the bullet interacts with targets. Examples include what happens when it causes wounds as well as its interaction with inanimate objects such as water, soil, concrete, wood, and other materials.



A bullet fired from a gun travels at supersonic speeds. This picture shows a bullet and the air flowing around it. The bullet is traveling at 1.5 times the speed of sound. (At sea level, at a temperature of 68°F, the speed of sound through the air is roughly 768 mph. Therefore, this bullet is moving at approximately 1,152 mph.)

FOR GREATER UNDERSTANDING

Questions

1. List six categories of shooting incidents.
2. Discuss the fragile evidence associated with shooting scenes.
3. What is GSR? What is its origin?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Garrison, Dean H. *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Boca Raton, FL: Universal Publishers, Inc., 2003.

Haag, Lucien C. *Shooting Incident Reconstruction*. Burlington, MA: Elsevier Academic Press, 2006.

Hueske, Edward E. “Ballistics.” *Practical Analysis and Reconstruction of Shooting Incidents*. Pp. 267–78. Boca Raton, FL: CRC Press, 2005.

Lecture 10 Notes

1. St. Valentine’s Day Massacre information at the *New World Encyclopedia*. — http://www.newworldencyclopedia.org/entry/Saint_Valentine%27s_Day_Massacre.
2. Article by Christine Hauser reporting on the Virginia Tech slayings for the *New York Times*. — http://www.nytimes.com/2007/04/16/us/16cnd-shooting.html.
3. Article by Anne Kornblut reporting on the accidental shooting by Vice President Cheney for the *New York Times*. — http://www.nytimes.com/2006/02/13/politics/13cheney.html.
4. Article by Robert D. McFadden reporting on the shooting at Ft. Hood, TX, for the *New York Times*. — http://www.nytimes.com/2009/11/06/us/06forthood.html.
5. Haag, Lucien C. *Shooting Incident Reconstruction*. Pp. 6–12. New York: Elsevier/Academic Press, 2006.
6. Ibid.
7. Schwoeble, A.J., and David L. Exline. Chapter 1. *Current Methods in Forensic Gunshot Residue Analysis*. Boca Raton, FL: CRC Press, 2000.
8. Haag, Lucien C. *Shooting Incident Reconstruction*. P. 199.
9. Ibid. Pp. 187–96.
10. Ibid. Pp. 199.
11. Heard, Brian J. Chapter 2, “Ammunition.” *Handbook of Firearms and Ballistics*: *Examining and Interpreting Forensic Evidence*. 2nd ed. Hoboken, NJ: Wiley-Blackwell, 2008.
12. Ibid.
13. Hueske, Edward E. “Ballistics.” *Practical Analysis and Reconstruction of Shooting Incidents*. Pp. 267–78. Boca Raton, FL: CRC Press, 2006.
14. Haag, Lucien C. *Shooting Incident Reconstruction*. Pp. 213–34.

Lecture 11

Shooting Scenes, Part Two

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 20, "Introducing Shooting Scene Investigations."

At most shooting crimes, bullets travel in straight lines, and determining their paths and understanding how they interact with surfaces is an important aspect of reconstruction.

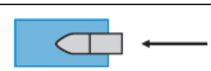
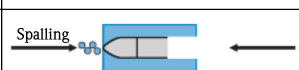
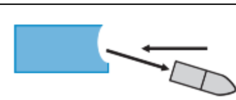
Bullets: Locard's Exchange Principle in Action

Bullets can be treasure troves of forensic information. Bullets must be found, collected, and preserved because protecting the forensic information is critical. In addition to human injury, an obvious aftermath of firearm discharge is the mark its bullets and projectiles leave on surfaces at the scene. Like all topics, bullet impact marks (BIMs) have a language with which the scene scientist/investigator should be familiar. These are described in Table 11.1.[1]

Identifying Bullet Strikes

Bullets strike targets in various ways, and, like bullets and their defects, these have a language of their own. Figure 11.1 illustrates these for bullets striking a wall.

Figure 11.1: Common Bullet Mark Terminology

Term	Meaning	Illustration
Perforation	Bullet enters and exits target.	
Penetration	Bullet enters target but does not exit.	
Imbed	Bullet just enters target but is not completely inside.	
Spall	Bullet enters target and punches debris on exit side without exiting.	
Deflection	Bullet hits target and then changes direction, not entering target.	

Adapted from Garrison, Dean H. *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Boca Raton, FL: Universal Publishers, Inc., 2003.

The on-scene identification of which holes/defects result from a bullet strike is important because, if misinterpreted, the investigation can result in an incorrect and flawed reconstruction of the incident's events.

Table 11.1: Firearms-Related Terms

Term	Description
Primer	The mechanism for igniting the propellant. Rimfire ammunition: firing pin crushes a soft hollow rim of the cartridge to explode the primer. Center fire ammunition: Primer held in a cup in the base of the cartridge. Primer crushed by firing pin.
Propellant	A mixture of chemicals that must be ignited from a primer. Ignited propellant produces gases that propel the bullet down the barrel of the firearm.
Cartridge Case	A holder for the propellant and primer, not the bullet.
Straight Cased	Diameter is constant along length.
Bottle-necked	Long case narrows to hold the bullet.
Tapered Case	Old European style: Wide-based case gradually reduced.
Bullet	A missile that is either fired or unfired.
Pellets	Individual lead or steel balls for shotgun ammunition
Shot	Another term for pellets (for example, "lead shot").
Rimfire Ammunition	Short brass, generally 0.22 in. in diameter. Closed end is flat head with a hollow rim with primer. Firing pin strikes rim, which crushes and explodes primer. The resulting flame ignites propellant.
Center Fire Ammunition	Brass, the head is thick and heavy with a central recess or pocket for primer cap. A hole goes from the primer pocket to cartridge, allowing flash to reach the propellant.
Caseless Ammunition	The propellant surrounds the bullet as a single, solid piece. No cartridge. The primer is usually at the rear of the propellant. Not typically associated with shooting incident scenes.

Chemical Analysis of Bullet Holes and Other Defects

Together, the bullet and its holes/defects are classic examples of the Locard exchange principle in action, making them a potentially sacred class of multitasking physical evidence. They can tell an investigator what the gun was and who and what it struck along the way. The astute scene investigator must carefully examine recovered bullets visually, if for no other reason than to see what it has collected during its journey. First, it is necessary to identify those "holes or defects" made by a bullet, usually accomplished by a close visual inspection of the defect followed by chemical testing for lead or other primer components. Initially, this is a simple visual examination of the hole/defect using a magnifying glass with the unaided eye and using a hand-held microscope at about 40X magnification, if available. The purpose is to identify "bullet wipe," a gray outline surrounding the hole.

As a bullet travels down the barrel of a gun, its surface becomes contaminated with material from previous discharges of the weapon, some of which is carbonaceous material and condensed GSR. After leaving the barrel, the bullet flies though a cloud of rapidly condensing GSR, which also deposits onto the bullet's surface. After leaving the GSR cloud, the bullet might strike one or more targets, depositing surface contamination and part of its metallic content. Because there is so much material that can be transferred from the bullet to the defect, it is important to visually check the defect to get a "feel" for what is present. If bullet deposit—bullet wipe—is present, there is a good chance the hole/defect was made by a bullet. For practical purposes, a black or gray ring around the hole is diagnostic for bullet wipe. The larger the ring, the more carbonaceous material that was present on the bullet.

The second visual test is to use a handheld magnifying glass or a 40X microscope to search for trace evidence from the bullet's travel down the barrel, debris from other intermediate targets, and blood. Chemical spot tests of the holes/defects can help to identify the composition of the bullet. Trace evidence adhering to the hole/defect can be tape lifted or cast. This should not compromise chemical testing to identify the composition of the striking projectile[2] for the presence of lead, copper, or nickel.

Trace Evidence and Bullet Holes

If the bullet goes through a red, plaid shirt, the fibers might be imbedded on its nose, the ogive. If it was the second projectile through tempered glass, it might have a scored surface from the sharp edges of the already fractured glass. If it passed through human tissue, blood should be present. A bullet passing through the head of an individual might have adherent blood, hair, and bone particles. Thus evidence adhering to a bullet is fragile evidence and it must be treated with the reverence it deserves. This means handling bullets extremely carefully in order to preserve whatever fragile trace evidence is present on the surface. Torn fragments of the rifling of the barrel of the weapon are rough and easily distinguished from GSR, and this can also be carried by the bullet.

Blood from Bullets and Bullet Holes

A bullet passing through human flesh should have that person's blood on it. Theoretically, if it hits two people, the blood from both—a mixture of DNA—should be present. The caveat, however, is that the first person's blood could be diluted after passing through the second person, and detecting it might be beyond the capabilities of current technology. That does not mean that it will not or cannot be detected. If it is detected, the first person's blood should be the minor contributor to the mixture, which can be important reconstruction information, although the actual results will be case specific. Not finding a second contributor does not necessarily mean the bullet failed to pass through a second person. Such layering of DNAs can help in reconstructing the sequence of events of a shooting by positioning people in the projectile's path.

Bullet Flight Paths

Determining the path a bullet takes from the time it leaves the muzzle of the gun to its final target is important for understanding what happened during the event. The terminology can be confusing because bullet flight paths are sometimes erroneously referred to as trajectories.[3] For the short distances involved in most shootings, this is a misnomer because what is being determined in most shooting incidents is not a trajectory but instead a flight path in a straight line. For most shooting incidents, true trajectory analysis is irrelevant because of the short distances involved—estimated to average twenty-five yards.[4]

Identifying intermediate targets requires knowing what objects were hit, the bullets recovered to identify other intermediate targets based on the trace evidence present. Thus gentle handling while examining a bullet's surface is critical, as is packaging it properly in order to preserve its trace evidence for subsequent laboratory analysis. Some fatal bullets may be recoverable at the scene, but others will be identified during the autopsy and collected by the medical examiner. A bloody bullet does not mean it was a fatal projectile. Only the medical examiner can determine which bullets were fatal.

The investigation must identify and collect all firearms evidence before the number of weapons fired can be determined. If a bullet is unaccounted, reconstruction data will be missing, which can compromise the final interpretation of the events. Determining shooter position depends on the preservation of fragile evidence (for example, footwear impressions, cartridge case ejection patterns, and the accuracy of on-scene bullet path angular component measurements). If these are erroneous, the bullet path determination will be incorrect, as will be the positioning of shooter positions.

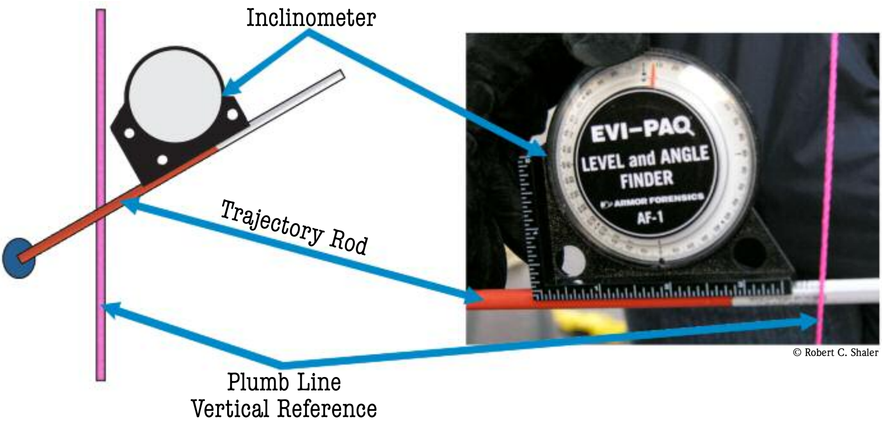
Bullet Flight Path Angular Components

Bullet flight paths are defined by their angular components, vertical and horizontal (azimuth). Without these, it is impossible to determine shooter positions in the absence of other physical evidence (footwear impressions, cartridge casings, and so on). Even with the other investigative information, defining the bullet's flight path accurately is critical to the reconstruction of the shooting events. One common method is to use trajectory rods inserted into the bullet hole, which works well for perforating bullet strikes in fixed objects having two points of bullet contact: an entrance and an exit. Trajectory rods tell investigators where a bullet could not have come from.[5]

However, if used improperly, the bullet flight path will be inaccurate and result in a faulty determination of the location of shooter position and a flawed reconstruction. Trajectory rods are available commercially or can be fabricated from wood dowels.

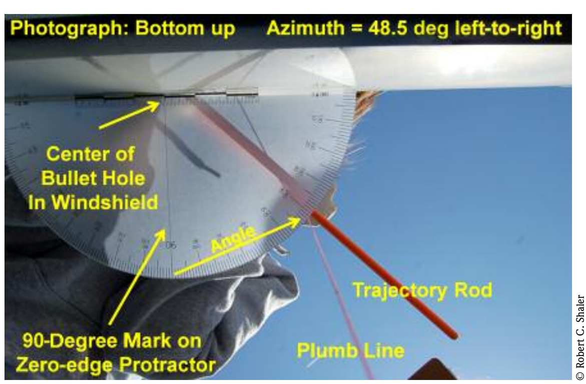
Figure 11.2 shows one method for determining the vertical angle of a bullet's flight path from a trajectory rod inserted into a bullet hole. A convenient method uses an inclinometer positioned on the trajectory rod.

Figure 11.2: Determining Vertical Angular Component Photographically



The horizontal angular component is determined using a zero-edge protractor. The 90° line on the protractor is placed in the center of the hole under the trajectory rod. A procedure for measuring the azimuth from a bullet hole in a windshield is shown in Figure 11.3. The photograph taken from under the zero-edge protractor shows the position of the bullet hole in the window, the perpendicular (90° mark) on the protractor, and where the plumb line touches the protractor. The angle is read from the perpendicular to where the plumb line touches the protractor.

Figure 11.3: Determining the Azimuth Using a Zero-edge Protractor



Ricochet

When a bullet strikes, several things can happen before it finds its terminus: it can enter the object, go through the object, or it can bounce or ricochet off the object. The point at which the bullet ricochets is determined by the structure and velocity of the bullet, the physical characteristics of the surface, and the angle at which the bullet strikes the surface. Although ricochet occurs at shallow angles of impact, as the impact angle becomes more acute, a point—the critical angle—will be reached when the bullet no longer ricochets and instead enters the object. Table 11.2 lists definitions of important terms that sometimes differ depending on the source. One glaring discrepancy is the concept of incident and impact angles. For some practitioners, the angle at which the bullet strikes the surface is the angle of incidence, while for others it is the angle of impact.

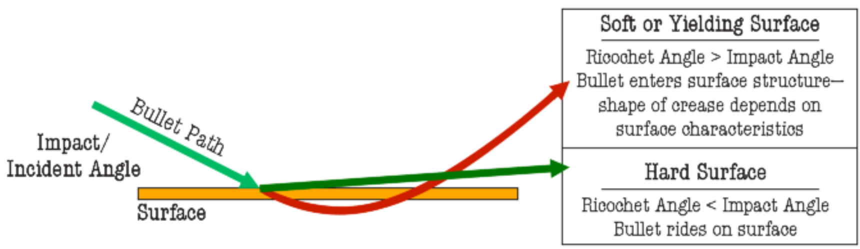
Table 11.2: Bullet Ricochet Terminology[6–8]

Term	Definition
Angle of Incidence or Angle of Impact	"The angle at which a missile strikes a surface before ricocheting." (Heard, Brian J.) "The intercept angle described by the pre-impact path of the projectile and the plane of the impact surface at the impact site when viewed in profile—differs from NATO method. To convert, subtract 90 degrees minus the forensic angle defined above." (Haag, Lucien C.) "The angle of incidence of the impinging bullet or pellet to the substrate." (Heard, Brian J.)
Angle of Ricochet	"The angle at which a missile leaves a surface after ricocheting." (Heard, Brian J.) "The angle formed between the path of the departing projectile subsequent to impact and the plane of the impacted surface." (Haag, Lucien C.)
Ricochet	"The deflection of a missile after impact." (Heard, Brian J.) "A change in angle and/or direction of a fired bullet or pellet as a result of impact with a substrate." (Heard, Brian J.) "The continued flight of a rebounded projectile and/or major projectile fragments after a low-angle impact with a surface or object." (Haag, Lucien C.)
Ricochet Mark	"A two-dimensional effect without discernible depth (such as a ricochet off an automobile windshield without surface penetration." (Heard, Brian J.)
Deflection (as opposed to ricochet)	"A deviation in a projectile's normal path through the atmosphere as a consequence of an impact with some object." (Haag, Lucien C.)

Ricochet and Surface Characteristics

Soft or yielding surfaces are those that are soft enough for the bullet to enter the surface's matrix (for example, sheetrock, wood, and automotive metal). How a projectile interacts with these surfaces is illustrated in Figure 11.4 (adapted from references[9–11]). The light-green arrow shows the bullet's incident path. The color changes to red as it enters the matrix of the surface. For these surfaces, the impact/incident angle is generally smaller than the ricochet angle, although this is not axiomatic.

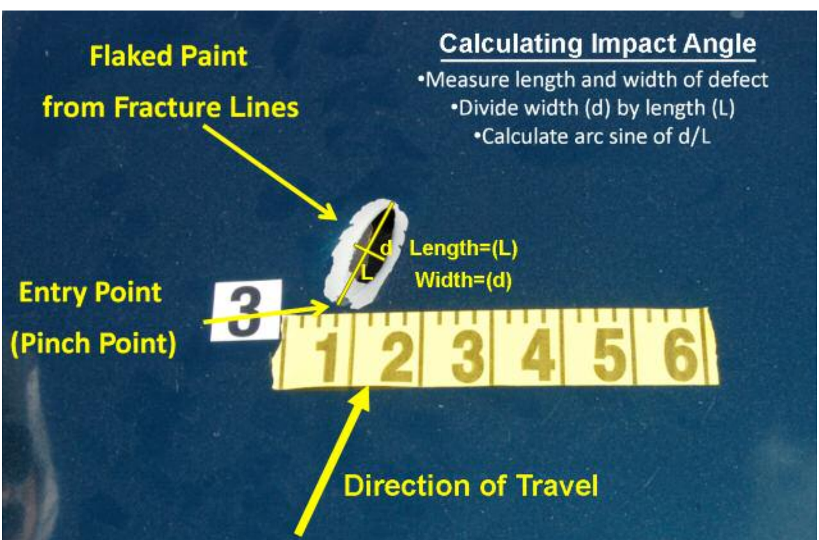
Figure 11.4: Ricochet from Soft and Hard Surfaces



Adapted: See references 9–11.

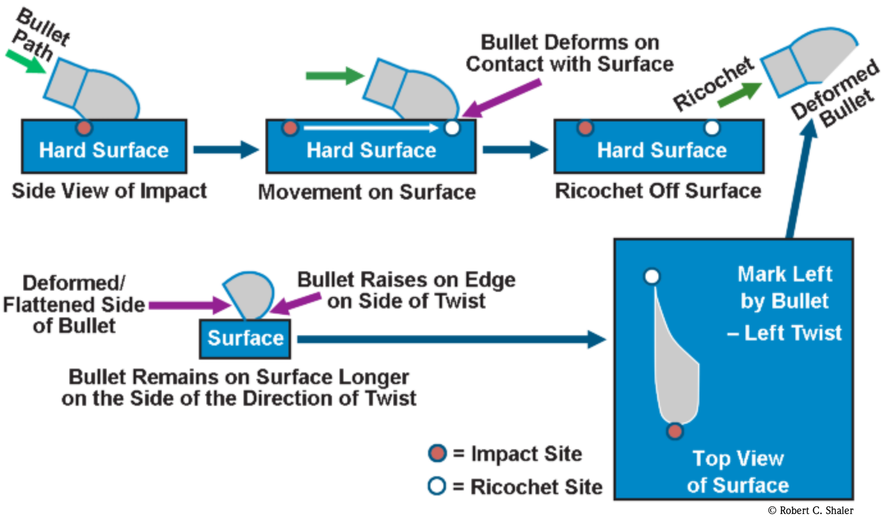
The angle of impact can be approximated for some surfaces by dividing the width of the defect by its length and then taking the arc sine of the fraction. An example is shown in Figure 11.5 for a bullet striking automotive sheet metal. From this, the bullet impact angle and its path can be inferred.

Figure 11.5: Bullet Striking Automotive Sheet Metal



Bullets that do not penetrate or perforate hard or unyielding surfaces can also ricochet. When that happens, the bullet strikes the surface, skims on top for a while, and then exits as a ricochet. Because the bullet rides the surface, the forensic information available is different from a soft or yielding surface. The diagram in Figure 11.4 illustrates how a projectile interacts with an unyielding surface. The light-green arrow shows the bullet's incident path. When it strikes the surface (dark-green arrow, Figure 11.4), it rides along the surface and exits, or ricochets. Its ricochet angle is typically less than the impact angle.

Figure 11.6: Identifying Twist from Bullet Impact Marks



Direction of Travel

The direction a bullet is traveling can be determined by examining the physical characteristics of the ricochet mark. From painted automotive sheet metal, the direction can be determined using other characteristics of the defect, and bullets striking painted sheet metal display certain diagnostic characteristics. These can indicate direction of travel by showing the place where the bullet struck the surface. Sometimes, the paint forms a visible knob (pinch-point arrow in Figure 11.5), where the projectile struck the painted surface. Sometimes, too, fracture lines or stress cracks form along the edge of the mark on painted surfaces, which point backward from the direction the projectile was traveling, much like the wake of a boat. Sometimes, the fracture lines cause the paint to flake off as in Figure 11.5.

Bullet twist refers to the spin imparted to the bullet by the lands and grooves of the barrel of the gun, right or left as it heads to a target. When the bullet hits a hard, unyielding surface, it rides along the surface longer, tilted on its twisting side. This is illustrated in Figure 11.6. If it has a right twist, that is, if it is spinning to the right when it hits the surface, it will leave a mark visibly elongated on the right side. These marks can be identified on hard or unyielding surfaces and can provide information about the bullet, even if the bullet is never recovered.

Additional surface characteristics must also be considered: semi-hard and semi-yielding. An example is road asphalt. A reliable indicator of ricochet from asphalt results from the physical characteristics of the mark or crease, which is the presence of fresh, sharp, fragile edges. If recognized early in the investigation before being worn away by traffic, investigators, or weather, they can be diagnostic of bullet impact.[12] Bullets striking asphalt can also have characteristic trace evidence: front-to-back striations, mineral inclusions, and tar-like smears. Because of the uneven nature of asphalt, ricochet and deflection angles are unpredictable. The bullet striking asphalt might have a right twist, but the deflection might be to the left simply because the bullet struck a small stone that was part of the physical structure of the asphalt.

Typically, frangible surfaces are composed of materials that tend to crumble when struck by a bullet/projectile: cinder block, bricks, and stones cast from mortar. These react like hard or unyielding surfaces until the combination of the impact velocity and the impact angle causes the material to shatter below the impact site, making the ricochet angle sometimes less than the incident angle, much like a hard surface.

Deflections

Essentially, a deflection occurs when a bullet/projectile deviates from the plane of its incident/impact angle. This happens as a result of ricochet or because of how the bullet/projectile interacts with the surface. An example is asphalt. A bullet/projectile can also perforate a surface and then exit in a plane that is not the same as the incident plane, right, left, up, or down. In these instances, the direction of the deflection is related to the twist of the bullet. When the bullet enters the material, it is spinning, and it will exit on the side of the spin: right spin, right deflection. The caveat is that the bullet must be in contact with the interior of the material for a period of time, depending on the material, to allow it to “grab” the texture of the surface sufficiently for it to change direction. For thin material, such as sheet metal, there is little or no deflection.

Packaging and Preserving Firearms Evidence

Protecting firearms/ballistic evidence from a shooting scene is critical. Most firearms evidence falls into specific categories: firearms, bullets, cartridge cases, ammunition, powder and shot patterns, GSR, serial number restorations, bullet holes, ricochet marks, and other defects. In collecting this evidence, handle the evidence with gloved hands or plastic tweezers, be aware of trace evidence, and package each item separately. Bullets and cartridges should not be marked, but all packaging must be labeled properly. Firearms must be rendered safe. Generally, powder patterns are found on the skin of victims (fouling and stippling) or on clothing. Archive these photographically and if possible collect the evidence (for example, clothes) at the scene and package so that no transfer of evidence can take place from one part to another. The most appropriate way to package the GSR on clothing is to wrap it in paper as though preserving bloodstain evidence.

FOR GREATER UNDERSTANDING

Questions

1. What is bullet wipe?
2. Discuss the angular components of a bullet path.

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Garrison, Dean H. *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Boca Raton, FL: Universal Publishers, Inc., 2003.

Haag, Lucien C. *Shooting Incident Reconstruction*. Burlington, MA: Elsevier Academic Press, 2006.

Hueske, Edward E. "Ballistics." *Practical Analysis and Reconstruction of Shooting Incidents*. Pp. 267–78. Boca Raton, FL: CRC Press, 2005.

Lecture 11 Notes

1. Garrison, Dean H. *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Pp. 13–16. Boca Raton, FL: Universal Publishers, Inc., 2003.
2. Haag, Lucien C. *Shooting Incident Reconstruction*. Pp. 41–62. Burlington, MA: Elsevier Academic Press, 2006.
3. Ibid. P. 147.
4. Firearms staff, FBI Academy. October 1969, revised March 1974. "Bouncing Bullets." FBI Law Enforcement Bulletin.
5. Garrison, Dean H. P. 37.
6. Hueske, Edward E. "Ballistics." *Practical Analysis and Reconstruction of Shooting Incidents*. Pp. 195–96. Boca Raton: CRC Press, 2006.
7. Heard, Brian J. *Handbook of Firearms and Ballistics*: *Examining and Interpreting Forensic Evidence*. 2nd ed. Pp. 203–4. Hoboken, NJ: Wiley-Blackwell, 2008.
8. Haag, Lucien C. Pp. 116–18.
9. Ibid. P. 116.
10. Hueske, Edward E. Pp. 195–211.
11. Jauhari, Mohan. "Approximate Relationship Between the Angles of Incidence and Ricochet for Practical Application in the Field of Criminal Investigation." *Journal of Criminal Law, Criminology, and Police Science*. 62(1): 122–25, 1971.
12. Haag, Lucien C. Pp. 128–29.

Lecture 12

Shooting Scenes: Vehicle-Involved Scenes

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 21, "Vehicles as Shooting Incident Crime Scenes."

Vehicles are often involved in shooting incidents. In these crimes, bullets do weird things. Understanding these interactions can lead investigators into retrieving and understanding firearms evidence.

Vehicles are an indispensible consequence of a modern society and thus are associated with hit-and-runs, kidnappings, homicides, sexual assaults, shootings, and other crimes. It makes sense to concentrate on vehicles involved in shooting incidents because shooting incidents are associated with most crime types and vehicles are often involved. A shooting incident involving a vehicle includes evidence categories covered in this lecture series, such as firearms evidence and biological evidence. Like any scene, vehicle-involved scenes must be archived, searched, and managed. In investigating vehicle shooting incidents, these lessons must be applied. In addition, the specific lessons of ricochet, deflection, and angular components of the bullet path apply equally to vehicle shooting incidents.

It should be readily apparent that vehicle-involved shootings can be extremely complicated. In fact, the vehicle, even one at a homicide, must be considered a scene unto itself, much like the body. And like a dead body, several analytical issues must be considered and evaluated carefully before a definitive statement about what happened can be rendered. Without question, the successful investigation of a shooting incident requires the rigid application of the scientific method, and unless this is done the final interpretation of the events will likely be erroneous.

Vehicle scenes are several scenes in one and they present problems not typical of other scenes. First, the macroscene/microscene comprises two parts: the outside and the inside of the vehicle, similar to the inside and outside of a house of a homicide. Each is important and each has macro- and microscene evidence. Second, the exterior and interior of vehicles do not provide an abundance of working space, especially the interiors. This certainly complicates the efficiency of the investigation. Generally, the outside of the vehicle will be examined at the scene, and its interior in a controlled environment.[1]

Outside the Vehicle

The outside of the vehicle is the conduit to the inside, so by Locard standards anyone who touched the vehicle must have left evidence behind. The macroscene elements associated with the exterior of the vehicle include footwear impressions, tire-track impressions, paint transfers, bullet holes, blood and tissue, glass, cartridge cases, and others. Microscene elements associated with the exterior can include, among other things, fibers, fingerprints, and trace evidence associated with bullet holes. What matters is that this evidence is not forgotten in the haste to track bullets through the vehicle. The outside of the vehicle must be investigated first so that fragile evidence is not lost. This does not include sticking trajectory rods into bullet holes. The sequence of a vehicle investigation is illustrated in Figure 12.1.

Figure 12.1: Investigating the Outside of Vehicles

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Investigation Sequence

Check for live or injured victims.
Treat the vehicle as a separate crime scene.
Follow a normal scene investigation sequence.

Investigate the outside of the vehicle first.
Search for macroscene and microscene elements.

Initial On-Scene Considerations

Archive the vehicle (photography, videography).
Treat bullet holes as Locard elements before analyzing paths.
Use ALS to search for fibers and fingerprints.
Dust/enhance fingerprints.
Search for and collect blood and tissue evidence.
Photograph and lift impression imprints on vehicle.

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The on-scene activity must be accomplished in a systematic and logical sequence. As with any scene investigation, archiving takes precedence. Archiving vehicles requires collecting as much information about the vehicle as possible, which includes still photography and video of the vehicle, including all four sides and license plates. Other information should also be obtained: VIN number, tire manufacturer and size, damage to the body of the vehicle, bullet holes, impressions in the paint, blood and fibers adhering to windshield, and tissue and blood on the undercarriage and tires. After photographing and videoing, use the ALS to search for fibers and fingerprints. Examine bullet holes or defects for trace evidence before attempting bullet-path determinations.

Inside the Vehicle

After investigating the outside of the vehicle, it is time to archive the inside of the vehicle. This begins with establishing shots (and video) of the interior, looking outside-in from all exterior aspects and then midrange shots through the windows and doors. Live victims should have been removed, a process that can compromise evidence. Deceased victims might still be inside the vehicle, and their positions must be documented. Macroscene evidence inside the car is important, such as the location and pattern of bloodstains, bullet holes, bullets and bullet fragments, cartridge cases, broken glass, and so on. There is also the question of who was where inside the vehicle, especially if the driver and passengers are not present. The position of blood and bloodstain patterns, fingerprints, and biological material on air bags can be an important mechanism for obtaining this information.

Vehicle Information

Vehicles have an abundance of information to share with investigators, and it is simply a matter of obtaining it. The vehicle-specific information is readily available, but the other information requires investigation, such as the positioning of the seats at the time of the shooting (seats can be moved to remove victims) or height and positions of windows and door openings. Most of the information is available from inspecting the vehicle during the archiving process. Additional information that should be obtained is shown in the following list.

- Manufacturer's diagram of vehicle can help with sketching.
- Behavior of vehicle in motion is important with respect to understanding how the vehicle will react in specific circumstances. If it is an older vehicle, it will likely not react as though it was new from the dealer. This information is only available through experimentation.
- Nature of scene terrain can be obtained by surveyor records or by analysis after the event. Some of the information, such as road contour, is obtained during the investigation.
- Ascertain how the scene terrain affects bullet paths to ensure that they are accurate.

Bullets and Vehicles

Vehicles pose significant problems in shooting incidents, specifically for determining bullet paths into and out of the vehicle. Generally, two separate activities take place when vehicles are involved in shooting incidents: on-scene and off-scene activities. The former takes place at the scene of the shooting and typically involves the archiving process, dusting/developing fingerprints, locating other impression evidence, blood, tissue, glass, and cartridge cases. The latter takes place at a controlled facility, such as a police-secured garage, where an intense investigation of the bullet paths and the interior of the vehicle begin. Here, two factors are involved: the different materials that make up vehicles and the issue of the vehicle in motion.

Vehicle Composition

Vehicles comprise various classes of structural material. These can be divided into two main groups: 1) the structural material that holds the vehicle together (for example, the frame, axles, drive shaft, and so on) and 2) nonstructural elements (although they may be structural in that they have form and shape) that are more practical and decorative rather than elements that maintain the integrity of the vehicle (for example, the dashboard, seats, interior door panels, and so on). Various materials complicate the analysis of bullet paths.[2, 3]

Vehicles in Motion

In addition to the material composition of vehicles, the fact that they can be or are in motion at the time of the shooting presents problems. An important consideration is precisely when and where bullets impacted the vehicle. Some of this information can be retrieved through statements of live victims or witnesses. Broken glass on the ground or bullet paths through a windshield can suggest the vehicle's position when bullets struck the windshield. Eventually the vehicle will stop and the aftermath of the shooting is reflected by the damage incurred. Tires are an issue because bullet strikes can deflate them slowly. Once flat, the vehicle is cocked at an angle that wasn't there before the shooting. Everything must be considered because an erroneous bullet path determination will lead to an incorrect reconstruction of the events. Figure 12.2 lists some complicating investigative issues that can occur in vehicle-related shooting incidents.[4]

Figure 12.2: Complicated Investigative Issues

- Vehicles in motion or not on level surfaces.
  - —Final resting place surface different from when struck by bullets.
  - —Struck location or orientation when struck difficult or impossible to determine.
  - —Relative position of doors and windows. (Can change during or after incident.)
- Shattered glass can be lost after incident.
- Laminated glass cracks continue post-event.
- Tires deflate slowly and go flat at location other than where shooting took place.

On-Scene Activity

Positioning the Vehicle

One of the first activities of the on-scene investigation is to position the vehicle. Since this is an outside activity, it occurs simultaneously with the archiving process. But what does positioning mean? Three aspects can affect reconstruction efforts and bullet-path determinations.

An effective method for re-creating the final resting position of the vehicle, important for reconstructing the shooting incident, is to spray a fluorescent line of paint beginning at the midpoint of all four tires (the axles) and moving onto the pavement. This effectively anchors the vehicle to that location on the roadway. The paint is semipermanent and marks the position of the vehicle's four tires at the original scene.

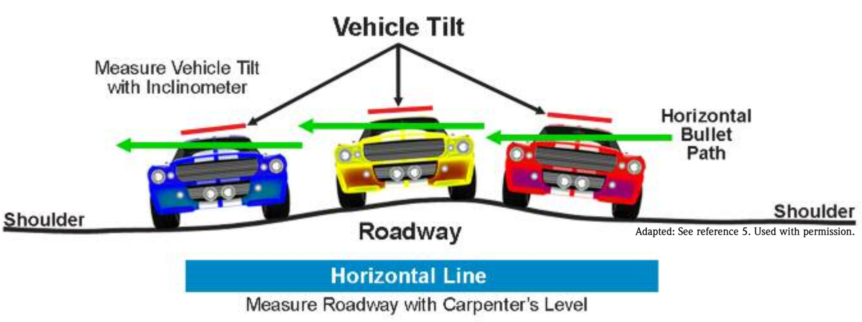
Determining Tilt of Vehicle

Vehicles are not always perfectly horizontal to the roadway after a shooting incident. An inclinometer placed on the trunk or hood of the vehicle (if it was an automobile) gives the resting angle of the vehicle. Certainly, a tilt can be the normal resting position for the vehicle for any number of reasons (for example, worn structural components, or it might be the consequence of the shooting incident, such as flattened tires).[5]

Contour of Roadway

Roads are not generally perfectly flat. In fact, the process of building roads requires making them higher in the middle than on the sides. In other words, they have contour to allow for drainage to minimize hydroplaning in wet weather. If a roadway is assumed to be flat or nearly so, the bullet paths will be erroneous. Figure 12.3 illustrates the point by showing the three vehicles positioned along the contour of the road. Each of the three vehicles has a different tilt as indicated by the red line above each. If a bullet is fired into each of the vehicles horizontally (green arrows), the path it takes will be determined by the tilt at which the vehicle lies. This means that each path can be different depending on which part of the roadway the vehicle sits, which can have serious consequences for reconstructing the incident. In Figure 12.3, the two vehicles on the left have similar bullet paths (green arrows) but these are different than the paths for the vehicle on the right. A banked roadway will give a different tilt to the vehicle.[6]

Figure 12.3: Effect of Roadway Contour on Bullet Paths



Tire Tracks

As discussed, the final resting place of the vehicle is not necessarily where the shooting began, which means investigators must attempt to determine where the shooting started. Sometimes tire tracks, such as skid marks, can help to determine where this happened because they indicate where the driver might have lost control, applied the brakes, or swerved. This information plus the bullet-path determinations and positioning of the shooter can help with reconstruction of the event.

Post On-Scene Activity

Measuring the Vehicle

Measuring the vehicle refers to determining vehicle-related measurements that include, among others things, the wheelbase and turning diameter. It also refers to measuring the vehicle to create reference points that describe bullet impact marks outside or inside. The post on-scene activity requires several steps: documenting bullet holes and defects and describing bullet holes and defects with respect to reference points.

Documenting Bullet Holes/Defects

Before determining bullet paths, bullet holes and defects should be documented. As with all forensic photographs, the close-up photos must have scales. The impact marks or holes must be measured to determine the impact angles, as illustrated in Figure 11.5. Measure the length and width of the mark using millimeter scales; the scale in the photograph is not appropriate.

Describing Bullet Holes/Defects

After taking establishing shots, take midrange and close-up shots of damage to the vehicle—impact points, bullet holes and defects, or other aspects of the vehicle. Next, in your notes, describe the defects so that anyone examining the case at a later time can understand their position. Do this by creating artificial vertical and horizontal reference points, a process that requires several measurements. The purpose of relating bullet holes/defects to a standard reference point is to create references so that all defects can be related. One method would be to use fixed points on the vehicle for each defect measured, such as trim, molding, or hook lines.[7] For example, a bullet hole in the driver's side door could be described (on a diagram of the door) as being six inches below the door handle and 21.5 inches to the right of the horizontal line drawn to the front edge of the driver's side door. One method for accomplishing this is known as the "Haag Method," or as "squaring the vehicle,"[8] and is an attempt to place the vehicle into a square box using tripods, tape measures, and string.

After the vehicle is removed from the scene and transported to a secure location and the initial archiving completed, the process of squaring the vehicle can begin. The process involves physically encompassing the vehicle inside an artificial box created using horizontally placed strings attached to tripods or other immovable objects. The horizontal references meet at a right angle, which becomes the standard reference point. All bullet hole/impact mark measurements are referenced to this point. Figure 12.4 illustrates the process.

The process takes place in a controlled environment on a smooth, level surface, and three measurements are taken in order to precisely position the hole/defect.

- Height of reference point.
- Angle from bullet hole/defect to reference point.
- Height off the ground of the bullet hole/defect on the vehicle.

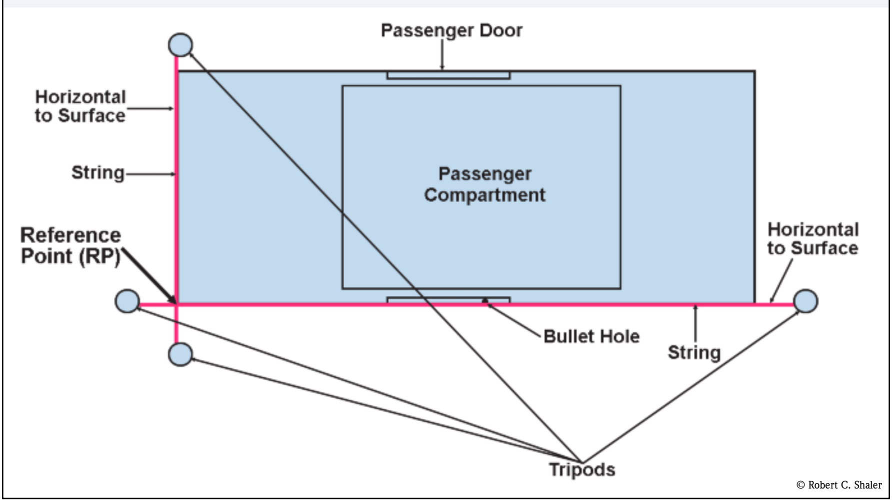
Figure 12.4: Haag Method for Determining Standard Reference Points

Vehicle Viewed as a 3D Rectangle

- At a subsequent "controlled environment."
- On a smooth, level surface.
- Flat surface—working space on four sides.
- Surfaces measured as needed (height of vehicle).
- Changes due to load.
- Roll/pitch changes measured.

Procedure

- Position four tripods with taut strings between each pair.
- One pair along the side of the car.
  –Parallels driver's side and just touches car.
- One pair across front and at right angle to other pair.
  –Just touches front of car.
- Reference point (RP) is intersection of strings at left front of vehicle.

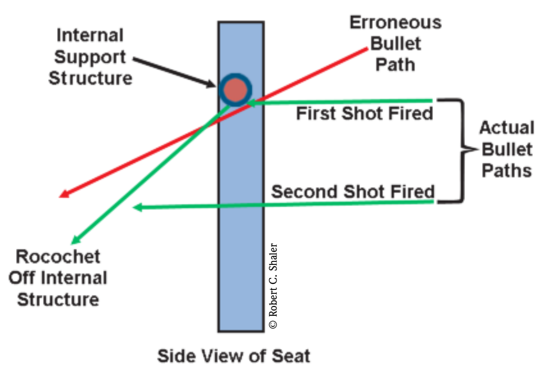


The Moran Method creates standard reference points for holes/defects differently. The process also takes place in a controlled environment on a smooth, level surface, and the standard reference point is determined by placing tape on the floor a set number of inches away from the vehicle determined by a specific distance from axle location on each tire. A vertical reference is tape placed vertically on the vehicle. Measurements from bullet holes/defects are related to the height and distance from the hole to the horizontal and vertical references.[9]

Perforating Strikes to Vehicles

When bullets perforate vehicles, anything can happen because the structural components complicate bullet path determinations. As the bullet enters the vehicle, whether through the windshield, a door, the trunk, or any other place, it encounters obstacles, which can fragment the bullet and create secondary projectiles or alter its path as a deflection or ricochet. Thus, tracking bullets through vehicles is a tedious process, invariably requiring dismantling interior parts. A hypothetical example is shown in Figure 12.5. Here, a bullet path was determined incorrectly because of the failure to recognize a ricochet off the internal structure of the seat. This led to two different shooter locations based on the incorrect bullet path (red). Had the investigator recognized the ricochet, he would have understood that the bullet paths from the first and second shots had been fired from the same horizontal trajectory.

Figure 12.5 Bullet Ricochet from Internal Door Structure



Penetrating (Nonexiting) Strikes to Vehicles

Bullets can strike, enter, but fail to exit. This complicates bullet path determinations because two points of contact are necessary to accurately identify a bullet path. If the second point of contact is a structural element inside a driver's side door. Seeing such points of contact is technically challenging because it requires cutting a hole into the door panel. A method for seeing inside the door is to cut viewing panels into the door. Here, a box is drawn on the door around the bullet hole. Next the box is cut, keeping the reference corners on the door. The cut-out is photocopied onto clear acetate, and the acetate is placed over the open hole on the door and then fixed to the door panel. The clear plastic provides a view inside the door panel so that the impact point can be observed and the bullet path determined.

FOR GREATER UNDERSTANDING

Questions

1. Why should automobiles be considered two scenes?
2. Illustrate how the contour of the road affects the accuracy of the bullet path into a vehicle.
3. Is archiving bullet holes in vehicles an on-scene or an off-scene activity?
4. What is meant by squaring the vehicle?
5. What is the purpose of squaring the vehicle?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Garrison, Dean H. *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Boca Raton, FL: Universal Publishers, Inc., 2003.

Haag, Lucien C. *Shooting Incident Reconstruction*. Burlington, MA: Elsevier Academic Press, 2006.

Hueske, Edward E. "Ballistics." *Practical Analysis and Reconstruction of Shooting Incidents*. Pp. 267–78. Boca Raton, FL: CRC Press, 2005.

Lecture 12 Notes

1. Garrison, Dean H. "Chapter 7: Vehicle Shootings." *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Pp. 72–73. Boca Raton, FL: Universal Publishers, Inc., 2003.
2. Haag, Lucien C. *Shooting Incident Reconstruction*. P. 269. Burlington, MA: Elsevier Academic Press, 2006.
3. Ibid. P. 267.
4. Ibid.
5. Moran, Bruce R. "Chapter 8: Shooting Incident Reconstruction." *Crime Reconstruction*. 2nd ed. P. 281. Eds. W. Jerry Chisum and Brent E. Turvey. San Diego: Elsevier Academic Press, 2007.
6. Garrison, Dean H. Pp. 86–87.
7. Ibid. Pp. 72–73.
8. Haag, Lucien C. Page 170–71.
9. Moran, Bruce R. Pp. 270–79.

Lecture 13

Forensic Bugs: The Importance of Insects at the Scene

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 16, "Forensic Entomology: Bugs and the Postmortem Interval."

> ***"How long's he been dead?" is a question asked by investigators at most homicide scenes. Sometimes only a forensic entomologist can provide the answer after studying flies and maggots at the death scene.***

Forensic Entomology

According to forensic entomologist Dr. Jason Byrd, "Forensic entomology is the use of the insects, and their arthropod relatives, that inhabit decomposing remains to aid legal investigations."[1] From a medico-legal perspective, this means determining the postmortem interval (PMI) or the time since death occurred by collecting insects at the scene followed by ascertaining the stage of their life cycles. The question of how long since someone died is a common investigative question, and investigators understand two processes taking place after someone dies: decomposition and the sequential appearance of entomological species signs at the scene.

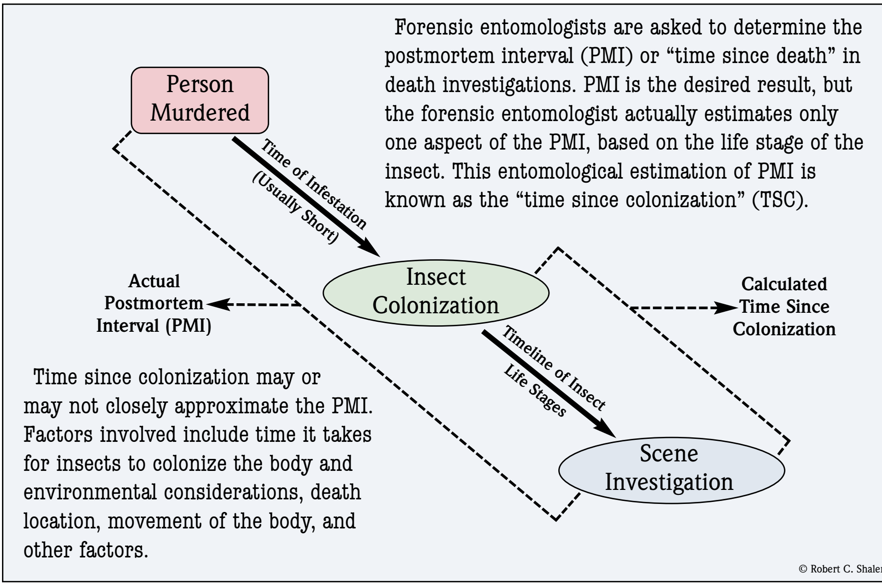
Insects are important for estimating the PMI because their life cycles predictably move from the egg to an adult in a process known as metamorphosis, a well-correlated, accurate process when environmental conditions are known. Medical examiners and forensic entomologists use the metamorphosis timeline to determine how long someone has been dead, which is helpful after the usual medical signals (rigor mortis, liver mortis, and so on) used by medical examiners are no longer relevant. Figure 13.1 shows the type of evidence expected at scenes requiring PMI determinations.

Figure 13.1: Entomology-Related Evidence

Decomposing body	Maggots/Maggot trails
Flies/Fly infestation	Animal distributed bones
Necrotic insects	Hidden/discarded weapons
Temperature	Firearms evidence (bullets, cartridges)
Footprint/tire tracks	Disturbed soil as evidence of additional burials

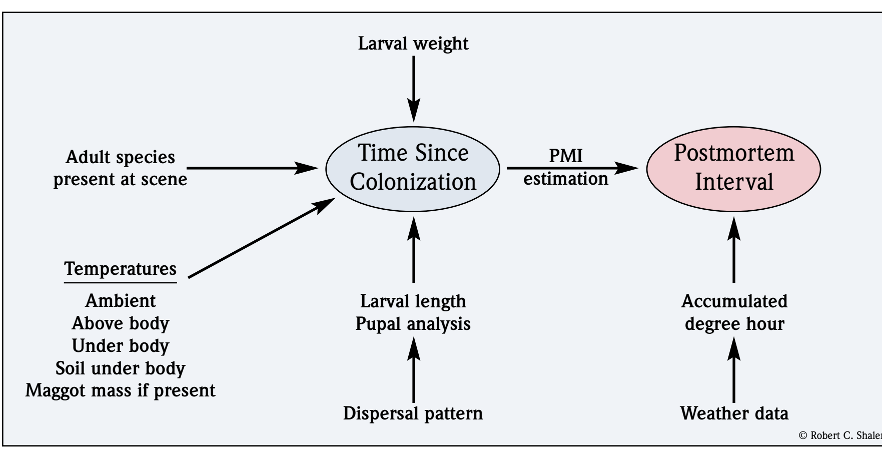
Importantly, entomological PMI estimates are just that, estimations. What is measured is the time it takes from insect colonization to the formation of the adult insect, which is known as time since colonization (TSC). Figure 13.2 illustrates the process.

Figure 13.2: Postmortem Interval: Time Since Colonization



After someone dies, such as in a murder case, insects colonize the body quickly after death. This is the time from when the person is murdered until colonization begins. Although it should be included in PMI estimate calculations, the TSC is not known. The physical data available to forensic entomologists is based on the physical presence of eggs, larvae, and adult insects. In addition, forensic entomologists require additional information, as shown in Figure 13.3. Obtaining this data accurately is important. Ideally, it should be obtained by a forensic entomologist or someone from the medical examiner’s office trained to collect the data.

Figure 13.3: Data Needed to Calculate PMI Intervals



Scene investigators need to recognize the stages of decomposition and the insects associated with each. By understanding metamorphosis and the associated insects, they will have the intellectual tools to know where to look for the insects and will be in a position to protect the appropriate evidence. It is apparent that some of the data necessary for PMI estimations is collected at the scene: obtaining the appropriate temperatures, capturing adult insect species, larvae, and pupae. If forensic entomological expertise is not available, the scene investigator should recognize the need to obtain these important items of evidence.

What Happens After Death

Importantly, insects are an integral part of decomposition, and by understanding the five stages of decomposition, the scene investigator can learn to associate the number and types of insects present in each. By associating which insects are present with each physical state of the body, the security of the entomological evidence has a better chance of being preserved. Table 13.1 shows the various stages of decomposition.

Table 13.1: Stages of Decomposition

Term	Definition
First Stage	Begins at the moment of death until onset of bloating. –Characterized by early stages in decomposition: algor mortis and liver mortis.[2]
Bloated Stage	Putrefaction begins. Gases from anaerobes cause inflation of abdomen. Temperature of carcass rises from putrefaction and metabolic activity of Diptera larvae. Fluids seep from openings. Soil under body becomes alkaline from larvae under carcass. Normal soil fauna under body leaves.
Decay Stage	Begins when skin breaks (sometimes classified as wet decomposition).[3] –Gases escape. –Remains deflate.
Post-decay Stage	Remains reduced to skin, cartilage, and bones (sometimes classified as dry decomposition).[4]
Skeletal Stage	Only bones and hair remain.

Finding the appropriate entomological evidence is critical but tedious, and mistakes can happen. For example, in a wooded investigation where bodies were found, investigators trampled a maggot trail so badly that the location of the largest larvae and pupae was destroyed. Since larval length is an important consideration of PMI, the resulting calculations were, at best, poor estimates.

PMI and Life Cycles

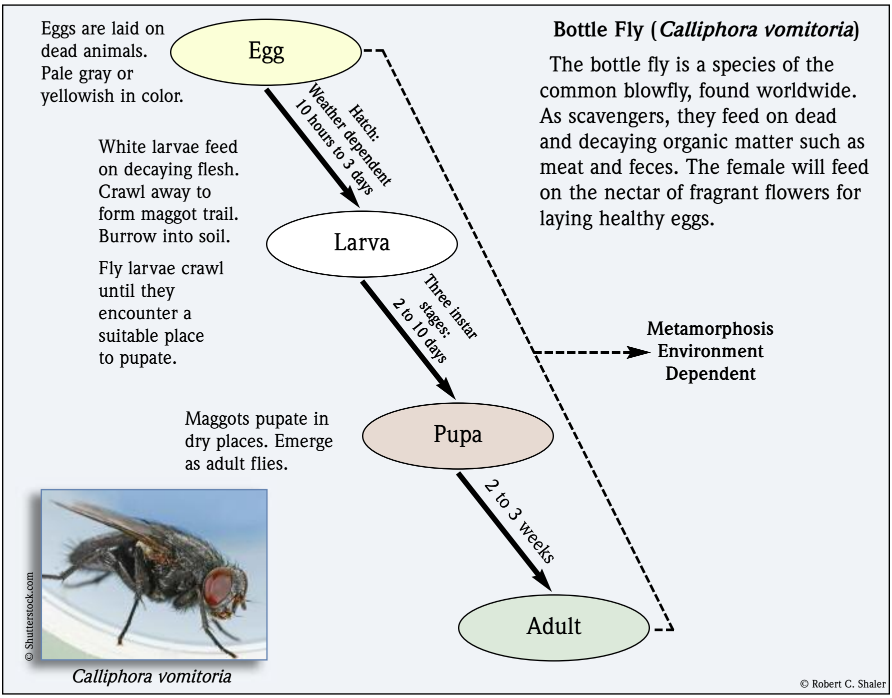
Insects sequentially colonize dead bodies because the body presents them with a continually changing food source that supports a succession of organisms, including bacteria, fungi, and vertebrate scavengers. The interest group to forensic entomologists is the arthropods, of which the main element of interest is insects. When they infest a body, a biological clock begins that allows for the estimation of the PMI. Although life-cycle analysis is well understood, PMI calculations are just estimations and only as good as the data collected from the scene and from existing and relevant weather data. If it is cold, the life cycle will be longer than when it is warm. Forensic entomologists certainly understand this and try to account for varying conditions, but precise up-to-the-minute determinations are not yet possible. In determining PMI estimations, the forensic entomologist studies the arthropods presented at the scene (see Table 13.2[5]).

Table 13.2: Insects Considered for PMI Estimations

Anthropod Group	Value in Estimating PMI
Necrophagous Species –Diptera (Calliphoridae and Sarcophagidae) –Flies	Probably the most important isolatable taxa for PMI estimations.
Predators and parasites of necrophagous species –Coleoptera –Parasites of Diptera larva (necophages in early decomposition become predators in later larval development).	The second most important group for PMI estimations.
Omnivorous Species –Wasps, ants, beetles –Feed on corpse and arthropods	Can adversely affect PMI estimations by removing (eating) necrophagous species.
Adventive Species –Use corpse as extension of normal habitat –Collembola, spiders, centipedes –Acari: Fungi feeders	Not as important for PMI estimations.

In the first group in Table 13.2 (Necrophagous species), the most common insect activity found early on dead bodies and soon after death is the bottle fly (Calliphoridae), of which there are two types, blue and green. Another early arriver is the flesh fly (Sarcophagidae). When these flies "smell" a dead body, they are drawn to it and begin laying their eggs, usually in orifices and open wounds, a process that can happen quickly depending on factors such as concealment, time of day, and the presence of drugs in the cadaver/carcass. The presence of eggs on a body marks the first visible stage of the insect development, and it begins the progression of metamorphosis or life stages. For the bottle fly there are four distinct stages: egg, larvae, pupae, and adult. These are illustrated in Figure 13.4.

Figure 13.4: The Four Stages of Metamorphosis



Learning to recognize the manifestation of a decomposing body, that is, the stages of decomposition, and to associate those with insects present at that stage requires knowledge of entomology and training. For example, if flies are in the area and rice-like particles (eggs) are present in the body's orifices the following information is known:

- The body is in the fresh stage of decomposition.
- Other physical manifestations, such as body cooling (algor mortise), blood settling (livor mortis), or rigor (joint stiffening), should be noted and photographed.

- Fly eggs are present in the animal's orifices and bottle flies are in the area.
- Larvae have not yet begun to form or, if they have, they have not dispersed far from the body.

If the stage of decomposition is more advanced, a larger number and species of insects will be present, and identifying them is important. Ideally, collect all the different species present. When the crime scene unit is dispatched to a scene, no one really knows what challenges it will present. From an entomological perspective, the crime scene mobile unit should have sufficient supplies and equipment to collect the critical entomological data and specimens necessary for calculating the PMI.

On-Scene Activity

Table 13.3 is a guide for collecting entomological evidence to ensure that nothing is missed.

Table 13.3: Guidelines for Archiving and Collecting Entomological Evidence

Activity	Method/Equipment Needed
Archiving: Photography and video	Establishing, midrange, and close-up photographs of all areas where insects and larvae/eggs are found. Also video area and insect/larvae relationships with body. Do not use flash to photograph larvae. • Maggot mass and temperature readings taken of mass and under body. • Detail of body structure changes. • Bite marks on living people.
Ascertain the stage of decomposition.	Recognize decomposition signs at each stage. Understand what specific insects should be present.
Use collection net to capture flying insects.	Wave the collection net over body in figure-eight pattern to capture flying insects. Place insects into collection jars.
Take temperatures.	• Ambient air • Under body • Soil under body • Maggot mass • Body temperature
Collect maggots.	Collect one spoonful of larvae from at least three maggot areas on corpse at scene.
Search for dispersed pattern of larvae.	Since individuals will bury themselves, it will be necessary to dig and then sift soil. Place larvae in collection jars. Collect larvae and pupae at dispersal points along the trail.[6]
Collect soil from under body.	Place spoonful of soil from various locations (documented photographically) in collection jar and cover with cloth.

After collecting the appropriate specimens, take them to the medical examiner's office, which will ensure they are delivered to a forensic entomologist who works with the medical examiner.

Arson and Entomological Survival

Experimental work suggests that important entomological evidence can survive house fires. This means that fire does not prevent insect colonization or the ability of the entomologist to determine the elapsed time since death. However, there are caveats. One is that fires will speed colonization rates by between one and four days, which can impact PMI calculations.[7]

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FOR GREATER UNDERSTANDING

Questions

1. What is PMI? TSC? How do they differ?
2. What is metamorphosis?
3. Why is metamorphosis the key to determining the PMI?
4. List the areas that require temperature readings.
5. Why is the maggot trail important for calculating PMI?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Byrd, Jason H., and James L. Castner, eds. *Forensic Entomology: The Utility of Arthropods in Legal Investigations*. Boca Raton, FL: CRC Press, 2000.

Lecture 13 Notes

1. *Forensic Entomology* website by Dr. Jason Byrd. — http://www.forensicentomology.com/definition.htm.
2. Voss, S.C., S.L. Forbes, and I.R. Dadour. "Decomposition and Insect Succession on Cadavers Inside a Vehicle Environment." *Forensic Science, Medicine, and Pathology.* 4: 22–32, 2008.
3. Gomes, Leonardo, Wesley Godoy, and Claudio José von Zuben. "A Review of Postfeeding Larval Dispersal in Blowflies: Implications for Forensic Entomology." *Naturwissenschaften* (*The Science of Nature*), 93: 207–15, 2006.
4. Goff, M.L. "Estimation of Postmortem Interval Using Arthropod and Successional Patterns." *Forensic Science Review*, 5(2): 82–94, 1993.
5. Ibid.
6. Ibid.
7. Anderson, G.S. "Effects of Arson on Forensic Entomology Evidence." *Canadian Society of Forensic Science Journal,* 38(2): 49–67, 2005.

Lecture 14

Mass Fatality Events and Bioweapons

The Suggested Reading for this lecture is Robert C. Shaler's *Crime Scene Forensics: A Scientific Method Approach*, chapter 15, "Mass Fatality Events, Bioweapons, and Microbial Forensics."

The attacks on the World Trade Center in 2001 opened America's eyes to terrorist attacks. Sometimes lost in that dialogue is the four Anthrax-laced letters sent to New York and Washington, D.C., that marked the dawn of a new discipline, microbial forensics or bioforensics.

Mass Fatality Events

Recent terrorist-inspired examples remain vivid: the World Trade Center Building bombing in 1993, the Oklahoma City federal building bombing in 1995, and the 2001 attacks on the World Trade Center and the Pentagon. Although human-inspired events are horrific, dramatic examples of the destruction caused by natural forces remain vivid: the 2004 and 2011 earthquakes that triggered tsunamis in Indonesia and Japan, respectively; the killer hurricane Katrina's destruction in Louisiana and Mississippi in 2005; and the 7.0 magnitude January 12, 2010, Haitian earthquake that claimed 230,000 lives, injured approximately 300,000, and left 1,000,000 homeless.

A recent position paper by the Department of Homeland Security[1] says that all human remains are to be recovered and that "complete documentation and recovery of human remains and items of evidence must be completed." The directives stress that mass-disaster scenes are to be considered crime scenes and that the customary rules of evidence and chain of custody apply.

A more insidious mega-fatality potential comes from bioweapons, which are silent, deadly, and fully capable of killing millions. Not solely disease causing, they are capable of contaminating water supplies and the food chain, thereby wreaking havoc in other insidious ways. In some respects, bioweapons are more deadly and destructive than bombings or natural mega-fatality events because their effects can be more far reaching and encompassing, as the example of the 2001 anthrax mailings in the United States starkly illustrated. For the purposes of this discussion, we will define mass-fatality events arbitrarily in terms of the resources required. If local resources are overwhelmed, and the governor of the state seeks federal help, then the event automatically becomes a mega-fatality event.

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The Anatomy of Mass-Fatality Events

The anatomy of mass-fatality events has two main parts: 1) the loss of life and structure and 2) the aftermath. We typically consider these in terms of rescue (the injured), recovery (deceased and missing), and cleanup (cleaning the rubble or an exposed area to weapons of mass destruction (for example, explosions, radiation, chemicals, and bioweapons).

The Human Consequences of Mass-Fatality Events

The pyramidal or hour-glass anatomical structure of mass-fatality events is an objective, statistical account of mass fatalities from loss of life, economic, and emotional perspectives. Not accounted for is the ongoing human struggle that continues well after these events. In fact, the anatomy of mass-fatality events drills deeper, occurring in sequence over long periods; its reality and aftermath never go away. The loss of life is tragic, and it affects the immediate family forever, but the long-term effects extend to the surrounding area and the public at large. For Americans, certain events are entrenched in our collective psyche: the 2001 attacks on the World Trade Center in New York City, the Pentagon in Washington, D.C., or the crash of Flight 93 in Pennsylvania. Nor will we forget the December 7, 1941, attack on Pearl Harbor or Hurricane Katrina in 2005. Each has a consequence structure that can be thought of as primary, secondary, tertiary, and perhaps deeper effects that begin at a point in time but never end. It begins with the most visible, headline event. The follow-on effects are not as visible, at least to the public. Table 14.1 shows the WTC sequence of effects that builds over time.

Table 14.1: Anatomy of the 2001 WTC Attacks

Event	WTC Example
Primary Effect	Planes hit the buildings
Secondary Effect	The Kill Zone
Tertiary Effect	Buildings Collapse
Quaternary Effect	Post-Traumatic Stress
Quinternary Effect	Lung Disease—Mental Illness

The anatomy of a bioweapon event is similar. There will be primary, secondary, tertiary, and quaternary events, at least, where the primary event is the release of the bioweapon. The secondary effect is the kill zone, which could be localized to a specific area or building, but it could spread across a much wider area. The tertiary effect will be people becoming ill and possibly succumbing to disease caused by a primary bioevent. The quaternary event relates to those who are emotionally traumatized by the primary event.

Bioweapons and Microbial Forensics

A stark example of a bioevent is the November 2001 mailing of letters in the United States containing *Bacillus anthracis* spores that claimed five lives and infected seventeen others. This single event confirms that bioterrorism is an ongoing threat. Unfortunately, bioweapons are not single dimensional, that is, they are not solely causative agents for disease. They can also target water and food supplies. Bioterrorism or biocrimes are defined as the threat or use of microorganisms, toxins, pests, prions (an infections agent composed primarily of protein unlike viruses), or their associated ancillary products to commit acts of crime or terror.[2]

If history is our guide, bioterrorism will likely involve multiple points of attack, as the 2001 *Bacillus anthracis* (anthrax) mailings dramatically illustrated. The components of these investigations are similar to, but are decidedly different from, traditional scenes of crimes. The similarities include components essential to all scene investigations: finding probative forensic evidence through competent management, archiving, searching, and so on. There are differences, however, and they are stark. In traditional scenes, the investigative paradigm is rooted in the Locard exchange principle, which predicts a transfer of evidence among the participants of the crime. This is typically how evidence originates. Bioterrorism or bioweapon scenes have a different operational paradigm.

- The participants might never meet because the spread of bioweapons does not require direct contact with the places of death or the victims.
- Bioweapon scenes pose a significant health risk to investigators and the public.
- The usual personal protective equipment (PPE) might not be appropriate for bioweapon scenes.

With the exception of seriously ill individuals or dead bodies, bioweapon scenes might not have a macroscene of traditional forensic evidence. That is, there might be nothing visible to suggest that a crime took place. In fact, the target of the bioweapon might be in the hospital.

In a typical bioweapons scenario people will become ill, and reports from physicians and health-related institutions to the Center for Disease Control (CDC) will trigger a public health investigation. If it is a bioweapon attack, the FBI will become involved. There are two biocrime scenarios: overt and covert.[3] The former, which will trigger law enforcement, is characterized by something at the scene that automatically raises suspicion (for example, white powder or suspicious envelopes or packages). In the latter, the public health mechanism is initiated after the outbreak of disease and is an epidemiological investigation as a concern for public safety. Law enforcement becomes involved secondarily to establish a legal framework for the case. This is what happened in the 2001 anthrax mailings with the first victim becoming ill in Florida after being diagnosed with inhalation anthrax.[4, 5]

Could this happen again? Assume terrorists learned a lesson from the 2001 anthrax mailings: Anthrax spores leaked from envelopes, contaminated mail-handling equipment, and infected mail handlers. Assume, too, that a bioweapon can be contained and carried into the United States undetected. Although the FBI's Dr. Douglas Beecher believes this is not feasible because it would be impossible to prevent the contamination of the outside of an envelope even if the inside could secure the bioweapon,[6] he confirms that it would be possible for a bioweapon to be stashed inside luggage (or a mailing box) and then inside a bioweapon-impenetrable material. The concealed bioweapon would be invisible to current counterterrorist measures. Once inside the country, the bioweapon could target selected individuals, religious groups, or important persons. If widely distributed, millions could become ill or die according to a terrorist's schedule.

A bioweapon scene is an insidious environment of death, and the absence of an obvious macroscene in a death investigation should be a red flag to investigators that something is not right (for example, multiple bodies, no apparent struggle, no blood, no locked doors, and so on). If sufficient time had passed, the bodies might show signs of infection like blood seepage. Such signs of biological infection should signal a bioweapon-related infection, if recognized. What if the terrorists inadvertently infected themselves? Two scenarios come to mind. In one, the terrorists seeking medical help would play out like a typical bioweapon scenario with reports from physicians to the CDC. But what if an inadvertently infected terrorist chooses not to act like the normally ill person and not go to a physician. Assuming a terrorist will act like a normal person is an assumption without a factual basis. Might not the terrorist choose instead to die without alerting authorities and use his remaining time to infect others wherever he could? Would that be more terrorist-like?

Throughout our discussions, I've constantly emphasized that the scientific method is the only logical method to ensure a successful investigation, a model that also applies to bioweapon scenes. The players have changed, and terrorism scenes are the responsibility of federal investigators, and the discipline emerging from the 2001 anthrax mailings is microbial forensics. A more apt name could be bioweapon forensics or bioforensics because bioweapons are not necessarily microbial or viral in origin.

Microbial Forensics

Microbial forensics is defined as a scientific discipline dedicated to analyzing evidence from a bioterrorism act, biocrime, or inadvertent microorganism/toxin release for attribution purposes.[7] Laying the foundation for microbial forensics is the responsibility of the Scientific Working Group on Microbial Genetics and Forensics (SWGMGF), an organization that focuses on defining quality assurance and analytical guidelines for laboratories, prioritizing efforts on likely pathogens and toxins, understanding and enhancing microbial population genetic data, and establishing design criteria for information databases.[8] Normally, public health officials, especially the CDC

(Centers for Disease Control), are the primary investigators for disease outbreaks, because they are charged with assessing the potential risk for disease and its spread. If it turns out to be a bioterrorism event, the forensic investigation begins with a mission that encompasses more than identifying the bioweapon and its spread. Both investigations occur simultaneously, and both need to identify the responsible bioweapon. That's where their investigations diverge. The forensic investigation focuses on preserving evidence for a legal proceeding, and the public health investigation with the spread of the causative agent. In a sense, the public health investigation and that of the forensic aspect are at odds.

Bioterrorism Terminology

In the wake of the 2001 anthrax mailings, the terms related to bioterrorism, Table 14.2, are commonplace. For the remainder of this discussion, the following definitions apply.[9]

Table 14.2: Bioterrorism Terminology

Term	Definition
Biocrime	A crime committed using biological weapons.
Bioweapon	A biological agent employed as a weapon.
Bacteria	A single-celled microorganism.
Virus	Protein/nucleic acid parasites that invade living cells, take over the cell's metabolic apparatus, and replicates, which causes the cell to burst and release new viral particles.
Biological Toxins	Biological molecules obtained from biological agents.
Bioscenes	Places that are the focus of bioterrorism events, which can include the target, the point of dissemination, or the point of manufacture of a bioweapon.
Bioevidence	Bioweapon collected as evidence during an official investigation.

Bioweapons

Conversations about biological weapons logically extend to the terrible consequences these weapons evoke: disease, suffering, and death. Unfortunately, anthrax is not the only bioweapon. In fact, examples include bacteria, viruses, and toxins, among others. Bacteria are ubiquitous and invisible. From a scene investigative perspective they are part of the microscene. As bioweapons, bacteria can create havoc in multiple ways. They can be directly lethal and incapacitating, contaminate the food supply by infecting plants and animals, and contaminate water supplies. Most bacteria that attack humans also attack animals.

Viruses are extremely small particles, the simplest type of common microorganism, consisting of a protein shell inside of which is a nucleic acid, either RNA or DNA. Smaller than bacteria, they invade a living cell, take over its metabolic apparatus, and replicate. Like bacteria, they kill and incapacitate by invading tissues and causing disease by producing toxins. They also attack people, animals, and plants.

Other potential organisms that are not as easily recognized by the general public include rickettsial pathogens and fungal pathogens. Toxins are poisonous substances produced by animals, plants, or microorganisms.

The Bioscene

Unfortunately, the first responder, who is front and center with a bioevent crime, is alone. The good news is that there is little chance that local crime scene investigators will encounter a bioscene because the routine investigations of burglaries, homicides, sexual assaults, and so on are crimes that have little connection with biocrime perpetrators. The bad news is that there is no guarantee that this status quo will continue. The key to recognizing the danger is learning to recognize when things don't add up: a body without traditional evidence, powder without drug paraphernalia, suspicious packages, laboratory equipment, or subtle but strange odors.

Powder or Suspicious Envelopes/Packages

Suspicious packages and unknown powders are potential threats. Entering a scene and finding an unknown powder, which could be sugar or cocaine, but where there are no signs of drug paraphernalia or manufacture, should raise a red flag. Even packages or envelopes that do not have these characteristics could still harbor a bioweapon. The United States Postal Service has guidelines on its website for identifying suspicious packages. See Figure 14.1.[10]

A false-colored microphotograph showing anthrax spores magnified at over twelve-thousand times their actual size.

Figure 14.1: Suspicious Mail

If you receive a suspicious letter or package,

1. Handle with care. Don't shake or bump.
2. Isolate it immediately.
3. Don't open, smell, touch, or taste it.
4. Treat it as suspect. Call local law-enforcement authorities.

Look for

1. No return address
2. Restrictive markings
3. Sealed with tape
4. Misspelled words, addressed to title only, incorrect title, badly typed or written
5. Oily stains, discolorations, or crystalization on wrapper
6. Strange odor
7. Excessive tape
8. Rigid or bulky
9. Lopsided or uneven

If you suspect the mail may contain a

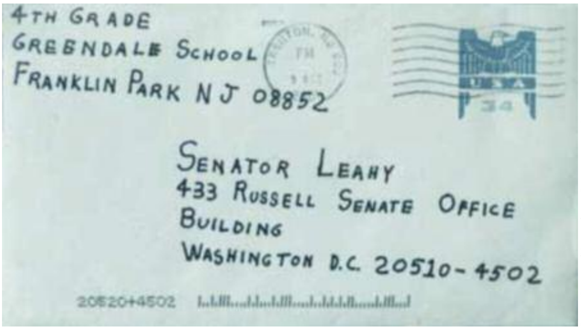
bomb: Evacuate immediately, call police, contact postal inspectors, and call local fire department or HAZMAT unit.

radiological threat: Limit exposure. Don't handle, evacuate area, shield yourself from object, call police, contact postal inspectors, and call local fire department or HAZMAT unit.

biological or chemical threat: Isolate. Don't handle, evacuate immediate area, wash your hands with soap and warm water, call police, contact postal inspectors, and call local fire department or HAZMAT unit.

The envelopes in the anthrax mailings had at least one and sometimes two of these characteristics. The letter sent to Senator Patrick Leahy recovered from the mailroom at the United States capitol building is an example (see Figure 14.2).[11] Its lettering was block-like (altered) and it had a false return address, which would not be known at the crime scene. The danger in handling envelopes and other packages is that the anthrax spores are small enough to penetrate the pores of the paper, which means that anyone handling the letters without proper protective equipment will be exposed, as will anyone in the area. In fact, the personal protective equipment will be contaminated,[12] which creates downstream issues.

Figure 14.2: Anthrax Letter Mailed to United States Senator Patrick Leahy in 2001



Public Domain/United States Department of Justice

Knowing how to handle suspicious packages and envelopes is important.

- Do not touch, sniff, taste, open, shake, empty, or look closely at the envelope/package or its contents.
- Do not touch, taste, smell, or sniff packaging contents that might have spilled.
- Place envelope/package on a stable surface.
- Alert others that a potential hazard exists.
- Leave the area, taking preventative action to ensure that potentially infectious material is not exposed to the face or skin.
- Call medical personnel for exposed or potentially exposed individuals.
- Obtain a list of persons who were in the area when the suspicious envelope/package arrived. Include in the list those who came into contact with the suspicious object.

On-scene Investigative Guidelines for Non-Hazmat Personnel

First responders are most at risk because there is no way of knowing what danger exists. Although most incidents are hoaxes, each must be treated as a real threat because the hoax is a criminal event, and it must be investigated. Standard procedures should be part of comprehensive training programs.[13]

Accidents at the Scene

What happens if there is an accident? Assume you or someone inadvertently touches or moves an envelope that has an unknown powder, and there appears to be no drug use at the scene. Assume further that the powder is anthrax or some other bioweapon. Unintentionally, you have not only contaminated the area (for example, floor, tables, and walls), but yourself and anyone in the immediate vicinity. The key to controlling the situation is not to panic. Immediately limit the exposed area and the number of people who might have been exposed. The following is a checklist of how to handle the situation.[14]

- There is no immediate danger. Relax and remain calm. Contain the contamination by not touching your face, eyes, nose, or mouth.
- Do not disturb the suspect material—letter or package—any further. Do not pass it around. Do not try to clean up the powder or brush it off your clothing.
- Stay where you are. Keep coinvestigators with you. Do not allow anyone to leave the premises.
- Quarantine the area and stop others from entering.
- Call for backup and hazmat services.
- If facilities are close, wash your hands and wet your clothing to prevent aerosols.

- If possible, shut down the building's ventilation system and turn off fans or equipment that circulates air around the area.
- Wait for help to arrive.

Enter an unknown scene slowly and cautiously. Walk through the scene carefully and focus not only on the obvious crime, but on signs that bioweapons or other weapons of mass destruction (WMD) could be present. Even a run-of-the-mill homicide could be where bioweapons or WMD are manufactured and distributed. Because such threats will increase, the first order of business is to ascertain whether a bio-threat is present. These might be obvious to someone versed in the science, but two questions must be answered for any scene.

1. Is laboratory equipment present and what kind is it?

   If the answer is yes, it could mean one of three things:

   a. Bioweapons or WMD are being manufactured.

   b. It could be a clandestine laboratory.

   c. There is an innocent explanation. (Never assume this.)

2. Are suspicious envelopes or packages visible?

   If not, treat the scene like any crime scene investigation, but remain vigilant. Follow normal guidelines for managing the scene.

   If yes, call for immediate and appropriate backup and secure the scene. Assume the following:

   a. The scene contains bioweapons or other WMD.

   b. The scene is contaminated with the bioweapon.

   c. The first responder has been contaminated.

   d. Anyone who is or was at the scene has also been contaminated.

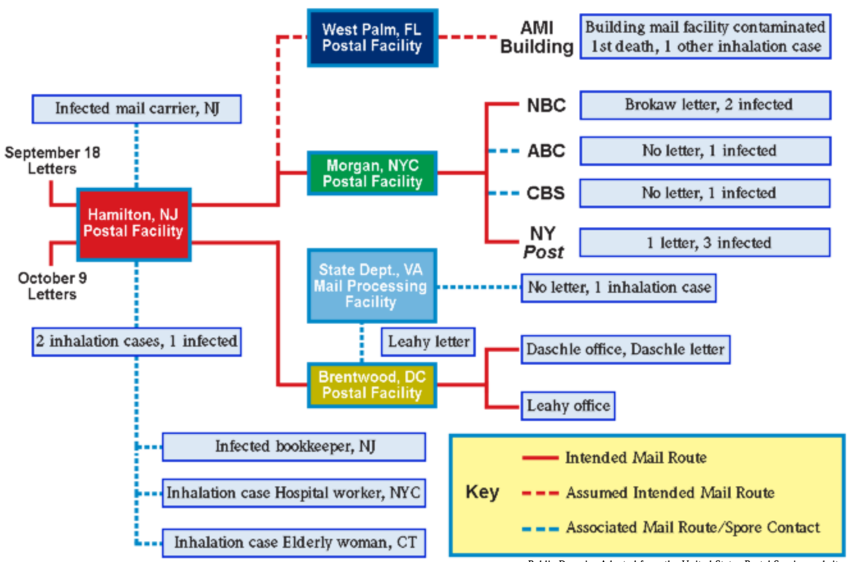
In these situations, the first responder has two responsibilities: Detain anyone at the scene so that bioweapon contamination remains at the scene. Without touching anything, attempt to ascertain whether the envelope or package has been opened. Even if the envelope or package appears intact, dispersed bioweapons are typically invisible even when using eye-aided techniques such as flashlights or an ALS. Small bioweapons, such as anthrax, can penetrate envelopes.

The Spread and Collection of Bioagents at the Scene

Fortunately, some studies concerning the difficulty of obtaining biomaterial from crime scene locations has been studied for anthrax. The data show that the surface and the collection method dramatically affect the ability of investigators to collect bioweapon evidence. Even after the CDC and the FBI have completed their investigations and have left the scene, the area must be decontaminated. The collection of anthrax spores from mailroom facilities where anthrax was located after the 2001 anthrax mailings showed that premoistened wipes and a HEPA vacuum sock (87- and 80-percent recovery, respectively) were more efficient than wet swabs (54 percent) and dry swabs (14 percent) for collecting spores.[15]

The relevant lesson learned from the 2001 anthrax mailings: Anthrax spores are easily spread to those who are not direct targets. In all, twenty-two people were infected, five of whom died from presumably five letters. Eleven of those victims had inhaled anthrax spores. Figure 14.3 shows the distribution of anthrax spores to the intended victims and the relationship of the mail routes to those who were infected or died but were likely not the intended targets. The range of the anthrax spread is obvious. Two letters were sent to New York, two to Washington, D.C., and presumably one to the American Media, Inc. (AMI) building in Florida, believed to have been sent by the same person.[16]

Figure 14.3: Distribution of Anthrax Spores After 2001 Mailings



Public Domain. Adapted from the United States Postal Service website.

The 2001 anthrax mailings prove the point that pockets of deceased individuals can occur after a bioweapon attack. Fortunately, the cutaneous anthrax infection, lesions, and so on is easily diagnosed. But it can be missed: It is believed that one of the 2001 terrorists might have been infected with cutaneous anthrax. Had medical personnel recognized it sooner and law enforcement been alerted, the attacks of September 11, 2001, might have been avoided.[17]

FOR GREATER UNDERSTANDING

Questions

1. Define microbial forensics, bioscene, and bioweapon.
2. Describe the hallmarks of suspicious packages.
3. Bioterrorism scenes have two investigative priorities. Name them and explain each.
4. What are the eight steps investigators take at the scene if someone is accidently exposed to what could be a bioweapon?
5. What two questions should investigators ask to determine whether a biothreat is present?

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Budowle, Bruce, M.R. Wilson, J.P. Burans, Roger G. Breeze, and Ranajit Chakraborty. Chapter 1: "Microbial Forensics." *Microbial Forensics*. P. 1. Eds. Roger G. Breeze, Bruce Budowle, and Steven E. Schutzer. Burlington, MA: Elsevier Academic Press, 2005.

United States Department of Justice. *An Introduction to Biological Agent Detection Equipment for Emergency First Responders*. NIJ Guide 101–00. Washington, D.C.: United States Government Printing Office, 2001.

Lecture 14 Notes

1. United States Department of Homeland Security. *National Preparedness Guidelines.* 2007. — http://www.dhs.gov/xnews/releases/pr_1189720458491.shtm.
2. Budowle, Bruce, M.R. Wilson, J.P. Burans, Roger G. Breeze, and Ranajit Chakraborty. Chapter 1: "Microbial Forensics." *Microbial Forensics*. P. 1. Eds. Roger G. Breeze, Bruce Budowle, and Steven E. Schutzer. Burlington, MA: Elsevier Academic Press, 2005.
3. Budowle, Bruce, Steven E. Schutzer, Michael S. Ascher, Ronald M. Atlas, James P. Burans, Ranajit Chakraborty, John J. Dunn, Claire M. Fraser, David R. Franz, Terrance J. Leighton, Stephen A. Morse, Randall S. Murch, Jacques Ravel, Daniel L. Rock, Thomas R. Slezak, Stephan P. Velsko, Anne C. Walsh, and Ronald A. Walters. "Toward a System of Microbial Forensics: From Sample Collection to Interpretation of Evidence." *Applied and Environmental Microbiology*. 71(5): 2209–13, 2005.
4. Ember, Lois R. "Anthrax Sleuthing: Science Aids a Nettlesome FBI Criminal Probe." *Chemical Engineering News*. 18(49): 47–54, 2006.
5. Cole, Leonard A. *The Anthrax Letters: A Bioterrorism Expert Investigates the Attacks That Shocked America*. P. 197. New York: Skyhorse Publishing, 2009.
6. Beecher, Douglas J. "Forensic Application of Microbiological Culture Analysis to Identify Mail Intentionally Contaminated with *Bacillus anthracis* Spores*." Applied and Environmental Microbiology*. 72(8): 5304–10, 2006.

7. Budowle, Bruce, Steven E. Schutzer, Anja Einseln, Lynda C. Kelley, Anne C. Walsh, Jenifer A.L. Smith, Babetta L. Marrone, James Robertson, and Joseph Campos. "Building Microbial Forensics as a Response to Bioterrorism." *Science*. 301, 1852–53, 2003.

8. Scientific Working Group on Microbial Genetics and Forensics. "Quality Assurance Guidelines for Laboratories Performing Microbial Forensic Work." *Forensic Science Communications*. 5(4), 2003.

9. United States Department of Justice. *An Introduction to Biological Agent Detection Equipment for Emergency First Responders*. Pp. 7–8. NIJ Guide 101–00. Washington, D.C.: United States Government Printing Office, 2001.

10. United States Post Office. Guidelines on Suspicious Mail. — http://www.usps.com/cpim/ftp/bulletin/2004/html/pb22119/suspicious.htm.

11. Federal Bureau of Investigation. Anthrax envelopes investigation. — http://www.fbi.gov/about-us/history/famous-cases/anthrax-amerithrax/the-envelopes-4.

12. Cole, Leonard A. P. 197.

13. Anderson, T. Bruce. Biosafety Officer, Department of Health, Safety, and Environment, The University of British Columbia. "Anthrax Letters Background Information and Response Guidelines." — http://www.zoology.ubc.ca/zoology/anthrax.html.

14. Ibid.

15. Sanderson, W.T., M.J. Hein, L. Taylor, B.D. Curwin, G.M. Kinnes, T.A. Seitz, et al. "Surface Sampling Methods for *Bacillus anthracis* Endospore Contamination." *Emergency Infectious Diseases*. 8: 1145–51, 2002.

16. United States Postal Service. "United States Postal Service Response to the General Accounting Office Recommendations on the Anthrax Attacks of 2001." — http://www.usps.com/communications/news/security/final_gao.htm.

17. The *New York Times*. "A Nation Challenged: Bioterrorism; Report Linking Anthrax and Hijackers Is Investigated." March 23, 2002. — http://www.nytimes.com/2002/03/23/us/nation-challenged-bioterrorism-report-linking-anthrax-hijackers-investigated.html.

COURSE MATERIALS

Suggested Reading

Shaler, Robert C. *Crime Scene Forensics: A Scientific Method Approach*. Boca Raton, FL: CRC Press, 2011.

Other Books of Interest

Bevel, Tom, and Ross M. Gardner. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction*. 3rd ed. Boca Raton, FL: CRC Press, 2008.

Bodziak, William J. *Footwear Impression Evidence: Detection, Recovery, and Examination*. 2nd ed. Pp. 17–20. Boca Raton, FL: CRC Press, 1999.

Budowle, Bruce, M.R. Wilson, J.P. Burans, Roger G. Breeze, and Ranajit Chakraborty. Chapter 1: “Microbial Forensics.” *Microbial Forensics*. P. 1. Eds. Roger G. Breeze, Bruce Budowle, and Steven E. Schutzer. Burlington, MA: Elsevier Academic Press, 2005.

Byrd, Jason H., and James L. Castner, eds. *Forensic Entomology: The Utility of Arthropods in Legal Investigations*. Boca Raton, FL: CRC Press, 2000.

Champod, Christophe, Chris J. Lennard, Pierre Margot, and Milutin Stoilovic. *Fingerprints and Other Ridge Skin Impressions*. Boca Raton, FL: CRC Press, 2004.

Committee on Identifying the Needs of the Forensic Science Community. *Strengthening Forensic Science in the United States: A Path Forward*. Pp. 127–91. Washington, D.C.: National Research Council of the National Academies, 2009.

Cooper, Cynthia L., and Sam Reese Sheppard. *Mockery of Justice: The True Story of the Sheppard Murder Case*. Pp. 5–13. Boston, MA: Northeastern University Press, 1995.

Eckert, William G., and Stuart H. James, eds. *Interpretation of Bloodstain Evidence at Crime Scenes*. 2nd ed. Boca Raton, FL: CRC Press, 1999.

Gardner, Ross M., and Tom Griffin. “Foundations for the Discipline of Bloodstain Pattern Analysis: A Response to the Report by the National Academy of Sciences.” *Journal of Forensic Identification*. 60(4): 477–94, 2010.

Garrison, Dean H. *Practical Shooting Scene Investigation: The Investigation & Reconstruction of Crime Scenes Involving Gunfire*. Boca Raton, FL: Universal Publishers, Inc., 2003.

Haag, Lucien C. *Shooting Incident Reconstruction*. Burlington, MA: Elsevier Academic Press, 2006.

Hilderbrand, Dwane S. *Footwear, The Missed Evidence*. 2nd ed. Wildomar, CA: Staggs Publishing, 1999.

Hueske, Edward E. "Ballistics." *Practical Analysis and Reconstruction of Shooting Incidents*. Pp. 267–78. Boca Raton, FL: CRC Press, 2005.

Lee, Henry C., and R.E. Gaensslen. *Advances in Fingerprint Technology*. 2nd ed. Boca Raton, FL: CRC Press, 2001.

Li, Richard. *Forensic Biology: Identification and DNA Analysis of Biological Evidence*. Boca Raton, FL: CRC Press, 2008.

MacDonell, Herbert Leon. *Flight Characteristics and Bloodstain Patterns of Human Blood*. Washington, D.C.: National Institute of Law Enforcement and Criminal Justice, 1974 (1971).

McDonald, Peter. *Tire Imprint Evidence*. Boca Raton, FL: CRC Press, 1992.

Montagna, William, ed. *The Structure and Function of Skin*. 3rd ed. Maryland Heights, MO: Academic Press, 1974.

Nause, Lawren. *Forensic Tire Impression Identification*. Ottawa, ONT: National Research Council of Canada, 2001.

United States Department of Justice. *An Introduction to Biological Agent Detection Equipment for Emergency First Responders*. NIJ Guide 101–00. Washington, D.C.: United States Government Printing Office, 2001.

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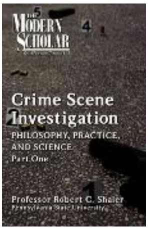

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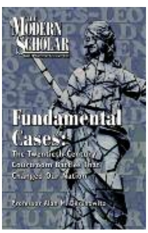

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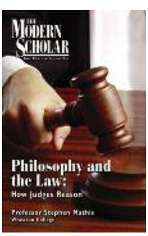

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