Introduction to Forensic Science & Criminalistics (2008)
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processed and released. That is why thorough documentation is so important. The 10 major reconstruction patterns we will discuss are as follows:

- Blood spatter
- Glass fracture
- Track and trail
- Tire and skid mark
- Clothing and article
- Gunshot residue
- Projectile trajectory
- Fire burn
- Modus operandi (MO)
- Wound, injury, and damage

Blood Spatter Patterns

blood spatter pattern
A pattern of dried blood on a surface resulting from an event that caused blood to exit the body and/or be broken into particles and distributed by force.

Blood spatter is probably the most common type of reconstruction pattern. **Blood spatter pattern** interpretation is something of a subspecialty in forensic science. There are laboratory examiners as well as investigators who specialize in blood pattern interpretation as a result of training and experience.

Basis of Blood Pattern Interpretation

Droplets of blood falling or projected through space follow standard physical laws. Those laws provide the scientific basis for understanding blood patterns.

By virtue of its makeup, viscosity, density, and other physical properties, blood forms predictable patterns when it falls, or is projected, through air and impacts a target surface.

Most of the time the blood forming a pattern of interest at a scene has already dried. But occasionally, it can still be in a liquid or semicongealed state. Blood deposited outside the body onto a surface will clot within a matter of minutes. Then it will dry. The larger the quantity of liquid in a blood deposit, the longer it will take to dry. Investigators sometimes use the state of the partially dried blood to draw inferences about how much time has elapsed since the blood was shed. Blood drying time will also be influenced by heat, humidity, air circulation, and the target surface. Such information must be taken into account in any attempt to predict time since deposit.

Velocity and Impact Angle

low-velocity blood pattern
A pattern caused by blood falling onto a surface, influenced only by the force of gravity.

Blood spatter is often classified as *low, medium,* and *high* velocity. A **low-velocity blood spatter pattern** is any pattern formed where gravity is the only force acting on the blood. These are typically dripping patterns (Figure 4.1A). According to the laws of physics, any body falling through space (including blood droplets) will reach terminal velocity (32 ft/sec.) after a certain distance of fall. Once a droplet reaches terminal velocity, the pattern it makes will not be different no matter how far it fell (although there might be air resistance or air current effects). Most dripping blood only falls a

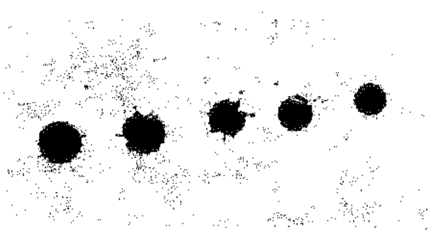

Figure 4.1A
Low-velocity blood spatter pattern.

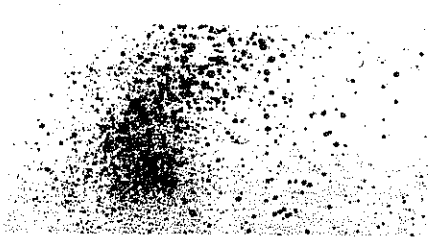

Figure 4.1B
Medium-velocity blood spatter pattern.

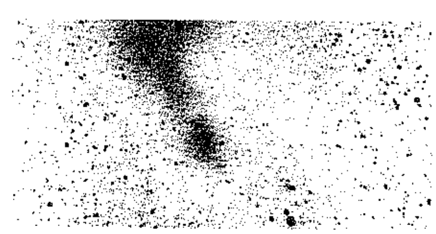

Figure 4.1C
High-velocity blood spatter pattern.

few feet—not far enough to reach terminal velocity. The force with which a droplet hits a nonabsorbent target surface affects whether "satellite" droplets are formed.

A **medium-velocity blood spatter pattern** is formed when moderate force from some object causes pooled blood to "scatter" in all directions surrounding the contact. The force causes the droplets produced to be smaller, so the resulting pattern consists of more and smaller droplets than are seen in typical low-velocity patterns (Figure 4.1B). These patterns are typically produced by an external force such as the use of blunt force to a bleeding source (such as a head), or someone stomping his foot or shoe into pooled blood. Medium-velocity spatter could also be produced by an arterial spurt.

medium-velocity blood pattern

A pattern caused by blood spattering in all possible directions from moderate force; many of the droplet stains are smaller than low-velocity pattern droplets and more numerous.

A **high-velocity blood spatter pattern** is the result of extreme force acting on a blood source (Figure 4.1C). As a rule, such patterns are seen only in connection with gunshots, explosions, or the high-impact forces of a vehicle crash.

high-velocity blood pattern

A pattern caused by blood spattering in all possible directions from extreme force, such as might happen with a gunshot or explosion; many of the droplet stains are very small (aerosol spray size) and often more numerous than in a medium-velocity pattern.

The shape of a blood spatter droplet indicates the angle from which it impacted the surface. A blood droplet hitting a nonabsorbent surface at a 90-degree angle (perpendicular to the surface) results in a circular stain. As the angle changes, the resulting stain becomes more elliptical (Figure 4.2A). In fact, using simple

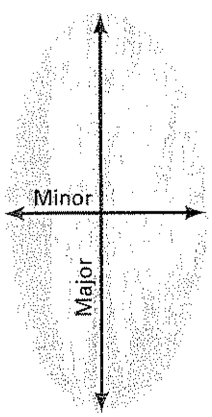

Figure 4.2A

Diagram of major and minor axis of an ellipse.

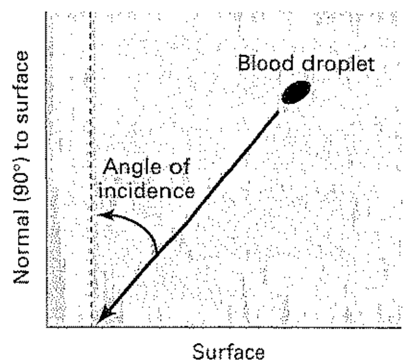

Figure 4.2B

Diagram showing the angle of incidence of a blood drop on a surface measured from the normal to the surface.

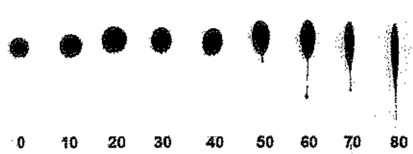

Figure 4.2C

Effect of angle of incidence on the shape of blood spatter dropped on a surface.

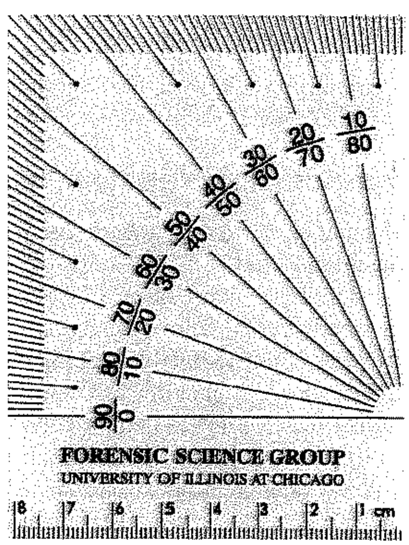

Figure 4.2D

A special angle scale measurement device.

More on the Science

Calculation of Blood Spatter Angle

A blood droplet impacting a nonabsorbent surface at exactly a 90-degree angle (exactly perpendicular to the surface) forms a circle pattern. Depending on the impact velocity, there can be satellite droplets around the outside of the circle, but the main pattern is a circle.

As the angle of the surface relative to the direction of the falling droplet changes from 90 degrees, the pattern becomes increasingly elliptical. Note that an ellipse is an "egg-shaped" two-dimensional figure that has a long diameter and a short diameter (Figure 4.3A).

There is a simple mathematical relationship between the properties of the ellipse and the angle of impact. The relationship is based on a trigonometric function known as the cosine. The cosine tables in various scientific and mathematical books and handbooks can be used to relate cosine values to angles. The cosine value is always a number between zero and one.

To figure the angle of impact for a blood droplet from its pattern, the major (long) and minor (short) diameters of the ellipse are measured as accurately as possible. Then the ratio of minor to major (width to length) is calculated. Because the measurements are used to compute a ratio, the units of measurement don't matter; that is, the measurements can be in inches, millimeters, and so on. Since the ratio is always that of a smaller to a larger number, the value will lie between zero and one. This ratio value is the cosine of the angle of incidence.

Expressed mathematically,

$$\cos\theta = \frac{\text{minor diameter}}{\text{major diameter}}$$

where we are designating the angle of incidence by the Greek letter θ (theta).

If you calculate the ratio of the two diameters in an elliptical blood pattern and then look up the angle corresponding to that ratio (cosine) in a cosine table, you get the angle of incidence.

It is important to note that the angle of incidence calculated using this formula is the angle of incidence of the blood droplet *with respect to a line perpendicular to the surface, not the angle with respect to the surface itself* (Figure 4.3C). Scales are available to make the angle estimation measurement easier (Figure 4.3D).

In a more complex pattern, such as a medium-velocity or cast-off pattern with numerous blood spatters, a selection of the droplet patterns can be measured and the angle calculations done. Then, straight lines (string, wires, etc.) can be drawn out from the droplet patterns at the estimated angles. The straight lines will tend to converge at a point that was the source of the blood pattern.

Note that the measurements generally cannot be that exact, so the resulting angles obtained are estimates. Although the straight lines will not converge to an exact point for that reason, they will usually converge to an area. These pattern reconstructions can tell an investigator approximately where the blood source (say, someone's head) was located at the time the pattern was formed. Experts may be able to tell, for example, whether a person was standing or lying down when a pattern was formed on a nearby wall, or whether a pattern in a vehicle is consistent with having originated from a person seated on the driver or passenger side.

angle of incidence

The angle at which a blood droplet impacts a surface, measured with respect to an imaginary line perpendicular to that surface.

measurements and some elementary trigonometry, the **angle of incidence** of a bloodstain can be estimated from the shape of the drop. See the "More on Science: Calculation of Blood Spatter Angle" box for a description of how this is done.

In a medium-velocity pattern, or a pattern that is partially medium and partially high velocity, the angle calculations can be used along with a straight line projection backward to the point of conversion (using strings, probes, or wires) to estimate the approximate origin of the blood forming the pattern, as noted in the "More on Science" box. A straight-line reconstruction is illustrated in Figure 4.3.

Various Blood Spatter Patterns

A number of blood patterns are commonly observed at scenes. We will describe them here briefly.

Falling droplets from a bleeding source that is stationary will generally result in blood pooling below the source. It may be possible to discern separate "droplet" patterns in the pool. If a dripping blood source is moving, blood "trails" can result. If the source is moving fast enough, the droplets may show which direction the source was moving (Figure 4.4A).

Contact deposit patterns result from an object coming into direct contact with a blood pool or blood source (Figure 4.4B). These patterns can appear on clothing or on objects at scenes. Sometimes, it is important to try to determine what object caused the pattern.

Wipe and swipe patterns result when an object contacts or transfers wet blood and smears it on a surface. A wipe pattern is created by an object contacting an existing bloody surface with motion. A swipe pattern is created by a bloody object contacting another surface with motion (Figures 4.4C).

An *arterial spurt* pattern results when an artery is cut or severed, and blood is literally pumped out of the body by the beating heart and onto a nearby surface. The repeated spurts cause a rather characteristic pattern. These patterns generally contain quite a bit of blood. In addition, an individual with a seriously severed artery is losing blood at such a rate that he or she will not be able to move too far and, without immediate and extreme medical intervention, will die fairly quickly.

Cast-off (also called *arc swing*) patterns result when a bloody object is swung through space and throws off droplets onto a nearby surface (Figure 4.4D). These patterns may be seen on ceilings or walls, even occasionally on floors. The most common action causing such a pattern is repeated use of blunt force on a person who is bleeding. This pattern was noted on the ceiling of the van in the lead case for this chapter.

Running patterns are just what the name says. Blood hits a vertical surface, but the volume is sufficiently high that gravity causes the droplet to run. Note that blood can only run down. As obvious as that statement is, it is sometimes quite helpful in reconstructing events from blood patterns.

Secondary spatter patterns result when blood drops fall into a preexisting pool of blood. As each drop hits the liquid surface, it can cause small droplets to splash upward, and some of these may hit a nearby vertical surface (Figure 4.4E). The

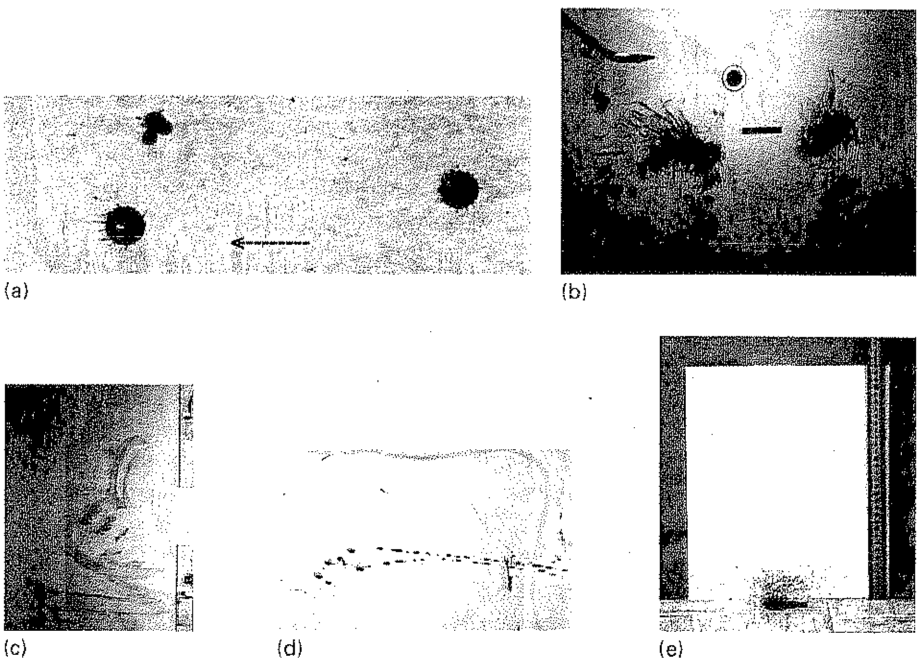

Figure 4.4A-E

A—Low velocity dripping pattern produced when the blood source is moving with respect to the target surface. The direction of movement can sometimes be discerned from the pattern.

B—Contact transfer pattern where a person's bloody hair made contact with the vertical surface. (Courtesy of Timothy Palmbach, University of New Haven)

C—Swipe pattern. (Courtesy of Timothy Palmbach, University of New Haven)

D—Cast off pattern. (Courtesy of Timothy Palmbach, University of New Haven)

E—Secondary spatter pattern. Blood dripping onto a hard floor surface causes a secondary spatter pattern on the nearby vertical surface. In this controlled setup, blood was dripping from 4 feet above the floor. The scale on the right side of the target is marked off in centimeters.

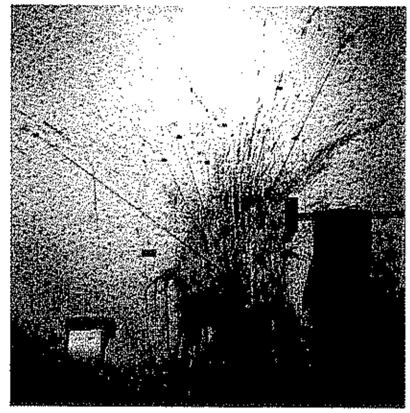

Figure 4.3

A straight-line reconstruction from a high/medium velocity blood spatter pattern. The straight lines formed by string are arranged at the angles of incidence calculated for selected droplets in the pattern. These lines converge approximately to a point. In this case, a person committed suicide in a bathroom by placing the muzzle of a shotgun in his mouth and firing. The blood pattern reconstruction confirms that the source of the blood was approximately in the position of the victim's head. The strings project outward from the wall into the room. (Courtesy of Timothy Palmbach, University of New Haven)

Case Study 4.1

Secondary Blood Spatter Patterns Help Solve a Homicide Case

Some years ago in a city in one of the mid-Atlantic states, a homicide occurred in which a man was thought to have murdered his estranged wife. There was enough evidence to arrest the suspect, but as prosecutors prepared their case, it became apparent that blood patterns on the suspect's clothing held the key to figuring out what had happened. Dr. Henry Lee was asked to look at the crime scene photographs, some of the physical evidence, and the suspect's clothing.

The victim lived in an apartment. On the date of the alleged murder, her estranged husband (who became the suspect and defendant) called the police to report that he had found her badly wounded and probably dying on the kitchen floor of her apartment. According to his account, she called him and said someone was trying to break in to her apartment. He lived a short distance away and said that he rushed to her apartment, only to find the front door locked. He broke a nearby window and climbed into the apartment. He then found the victim on the kitchen floor badly wounded and bleeding profusely. He said he knelt down, cradled her for a short time, then called the police.

Emergency responders arrived and removed the badly wounded victim. In doing so, blood pools and stains were stepped in, furniture was moved, and there were gurney wheel tracks in some of the kitchen floor bloodstains. Investigators took a number of color and black-and-white photographs at the scene. Two serrated-edge kitchen knives were recovered. Both belonged to the victim and were usually kept in kitchen drawers. One was on the living room sofa, and the other was on the kitchen floor. There was an extensive blood pool in the living room area, a bloodlike trail leading to the kitchen, and extensive blood pools and some contact transfers on the kitchen floor and on appliances close to the floor.

The victim died in the emergency room a short time after being transported. She was autopsied by the state medical examiner, who reported that cause of death was a single stab wound to the heart. The knife track was slightly upward of horizontal from slightly left of the midline below the heart directly into the heart. She had other stab wounds, some of which were characterized as "defense" wounds. The death was ruled a homicide.

The estranged husband's story sounded suspicious to investigators, and he was questioned and later arrested for the murder of his wife. He had a small wound on his left elbow. Police documented the wound in a picture. The clothing he was wearing—primarily the trousers and a jacket, both khaki, both extensively bloodstained—were seized by investigators.

On the outside of the jacket and trousers were numerous low- and medium-velocity blood droplet spatter patterns and contact transfer stains. The stains were present on the back of the jacket and on the backs of the trouser legs as well as the fronts.

Samples of bloodstains from the living room, the kitchen, the suspect's clothing, and the knives were shown to be human blood, and analyzed for ABO and isoenzyme types. (This case happened before the DNA era.) The blood and enzyme types were consistent with those of the victim and excluded the suspect. All the bloodstains could be from her.

commonest example of this pattern may be on the cuffs of pants that were located for a time near a blood pool into which drops were falling. Since the secondary droplets splash upward, the direction of the blood spatter pattern on the pants cuff will indicate that the blood came from the floor. This sounds unlikely until you realize that it could be secondary spatter. Case Study 4.1 illustrates the importance of secondary spatter in reconstruction.

Imprint and impression patterns that we will talk about in Part Three (fingerprints, footprints, footwear impressions) are sometimes made with blood. In the sense that they are imprints made in blood, they are also considered blood patterns. But they would be handled like other fingerprints, footwear impressions, and so on, from the standpoint of analysis and comparison. One important difference is that there are some special techniques for "enhancing" bloody imprints (discussed in Chapter 6) that may help make such patterns clearer or more visible and thereby more suitable for comparison.

Factors Affecting Blood Patterns and Their Interpretation

Blood pattern interpretation can be a very helpful tool in crime scene reconstruction involving bloodshed. Several things about blood pattern interpretation should be kept in mind, however. Considerable training and experience is generally required to become skilled in this type of work. Many of the principles concerning blood patterns we have previously discussed and illustrated are most accurate as related to patterns on nonabsorbent surfaces. On absorbent surfaces, the patterns may not be as clear. Their

The suspect's account of events could explain some blood transfer, especially contact transfer patterns on his clothing. He could have knelt in a blood pool, explaining a large stain on one trouser knee. And some bloodstains on the front of the trousers and jacket could have transferred from cradling the bleeding victim. The story did not explain medium-velocity patterns on the front of his jacket and trousers. And perhaps most telling of all, there were medium-velocity droplet patterns on the pants cuffs, which had traveled upward from the floor at a steep angle. Secondary blood spatter could explain these patterns. At some point, the person wearing these clothes was standing in or near a pool of blood, and new blood was dripping down into the preexisting pooled blood, causing secondary upward spatter. Nothing in the suspect's account could explain this blood pattern. Experiments were conducted in Dr. Lee's laboratory by allowing blood to drip from measured heights into a pool of blood on a hard floor with a white target surface nearby. At heights around 3 to 4 feet from the floor, the secondary spatter pattern could be replicated.

Based on Dr. Lee's examination of crime scene photographs, and the bloodstain evidence, the state theorized that the suspect came to the apartment wanting the victim to open the door for him. When she refused, he broke the window inward, and climbed in. Frightened, the victim went to the kitchen and got one of the knives to defend herself. As she came back into the living room, a struggle ensued and she was cut and wounded. She bled for some time in one location, creating the pooled bloodstain. The knife was knocked from her hand and landed on the sofa nearby. Next, she either freed herself and got the second knife, or the suspect did, and another close-in struggle took place. Near the kitchen door, the fatal wound was administered. The victim could not have moved far on her own after that wound, and the wound caused substantial bleeding. At a location in the kitchen, she bled for a time in one place, the place where the pooled bloodstain was later seen.

The blood patterns on the suspect's jacket and trousers resulted in great part from the two struggles in which the victim was cut and bleeding. The secondary spatter on the cuffs resulted from his standing in or near the blood pools as fresh blood dripped from the victim.

The estranged husband was convicted by a trial jury and received a long prison sentence. It is important to point out here, as we have in the main body of the chapter, that the state's overall reconstruction is a theory. Although the physical evidence record is consistent with the theory, it does not necessarily support every element. The movements of the people are somewhat speculative, for example. However, it is not likely that the secondary spatter pattern observed on the trouser cuffs could have been made in a way other than blood dripping into a preexisting pool. And nothing in the suspect's account of the incident explained why he would have medium-velocity blood spatter on his trousers or jacket, especially on the back sides of those garments. It was also certain that the bloodstains which were typed could not have come from the defendant but could have come from the victim. In this case, even if DNA profiling had been available, putting the victim's blood on the suspect's clothing was not alone sufficient to cast doubt on his own account.

shapes and angles may not even be obvious. Target surface absorbency, texture of the surface, and volume of blood are important variables in blood pattern formation.

Other factors that can affect interpretation include ambient environment, which can affect the time it takes blood to clot and to dry, and wind or air currents, which could alter the resulting blood patterns. Activities of the victim, suspect, witnesses, medical personnel, and police officers can also change the appearance of a pattern and complicate its interpretation.

In some cases, experts may conduct experiments to try and replicate patterns observed at a scene. The experiments might involve varying the amount of force, distances, or motion of a source with respect to a target surface. As noted in the discussion of reconstruction in Chapter 3, successful experimental replication of a scene pattern does *not* prove that the experimental conditions are those that prevailed at the scene when the original pattern was formed. Rather, it shows that the *theory* concerning the formation of the pattern is scientifically sound. This logic applies in Case Study 4.1 above. Replicating the patterns did not prove how the blood got on the pants cuffs, but showed that the theory was scientifically sound and reasonable.

It should also be noted here that scene reconstructions involving blood patterns cannot be done accurately without knowing whose blood was shed. Generally, dried blood samples from the patterns will be DNA profiled in the laboratory (Chapter 10) to associate the bloodstain with a person. At times, it appears safe to assume that only one person (usually a victim) was bleeding at a scene; a blood pattern reconstruction based on such an assumption should be considered conditional until the DNA typing results confirm it. Should the blood be from more than one source, the interpretation of the pattern could be significantly affected.