impact spatter
A bloodstain pattern produced when an object makes forceful contact with a source of blood, projecting droplets of blood outward from the source.

forward spatter
Blood that travels away from the source in the same direction as the force that caused the spatter.

back spatter
Blood directed back toward the source of the force that caused the spatter.

- The angle of impact of an individual bloodstain can be approximated by the degree of distortion or lengthening of the bloodstain, or it can be more effectively estimated using the width-to-length ratio of the stain.

Impact Bloodstain Spatter Patterns

The most common type of bloodstain pattern found at a crime scene is **impact spatter**. This pattern occurs when an object impacts the source of the blood. Spatter projected outward and away from the source, such as an exit wound, is called **forward spatter**. **Back spatter**, sometimes called *blow-back spatter*, is blood projected backward from a source, such as an entrance wound, and potentially deposited on the object or person who created the impact. Impact spatter patterns consist of many droplets radiating in direct lines from the origin of blood to the stained surface (see Figure 10-4).

FIGURE 10-4 Impact spatter produced by an automatic weapon. The arrows shows the multiple directions of travel from the origin of impact as several different bullets struck the target. *Courtesy, A.Y. Wonde*

Investigators have derived a common classification system of impact spatter based on the velocity of the force impacting on a bloody object. In general, as the velocity of the force of the impact on the source of blood increases, so does the velocity of the blood droplets emanating from the source. It is also generally true that, as both the force and velocity of impact increase, the diameter of the resulting blood droplets decreases.

CLASSIFYING IMPACT SPATTER

LOW-VELOCITY SPATTER An impact pattern consisting of a preponderance of large separate or compounded drops with diameters of 4 millimeters or more is known as **low-velocity spatter**. This kind of spatter is normally produced by gravity alone, by a minimal force, or by

an object dropping into and splashing blood from a blood pool. Low-velocity stains can result from an applied force moving at up to 5 feet per second.

low-velocity spatter
An impact spatter pattern created by a force traveling at 5 feet per second or less and producing drops with diameters of greater than 4 millimeters.

medium-velocity spatter
An impact spatter pattern created by a force traveling at 5 to 25 feet per second and producing drops with diameters of between 1 and 4 millimeters.

MEDIUM-VELOCITY SPATTER A pattern predominantly consisting of small drops with diameters of 1 to 4 millimeters is classified as **medium-velocity spatter**. This type of impact spatter is normally associated with blunt force trauma to an individual or with other applied forces moving at between 5 to 25 feet per second.

HIGH-VELOCITY SPATTER Very fine droplets with a preponderance of diameters of less than 1 millimeter are classified as **high-velocity spatter**. Here the spatter can result from an applied force of 100 feet per second or faster. Gunshot exit wounds or explosions commonly produce this type of spatter. However, because the droplets are very small, they may not travel far; they may fall to the floor or ground, where investigative personnel could overlook them.

Using droplet size to classify impact patterns by velocity is a useful tool that gives investigators insight into the general nature of a crime. However, the classifications of low, medium, and high velocity cannot illuminate the specific events that produced the stain pattern. For example, beatings can produce either high-velocity spatter or stain sizes that look more like low-velocity spatter. In general, one should use stain size categories very cautiously, and for descriptive purposes only, in evaluating impact spatter patterns. A more acceptable approach for classifying a bloodstain pattern should encompass observations of stain size, shape, location, and distribution.

Blood spatter patterns can arise from a number of distinctly different sources, which will be discussed in this chapter. Illustrations of patterns emanating from impact, cast-off, and arterial spray are shown in Figure 10-5.

ORIGIN OF IMPACT PATTERNS

Impact spatter patterns can offer investigators clues about the origin of the blood spatter and, therefore, the position of the victim at the time of the impact.

(a)

high-velocity spatter
An impact spatter pattern created by a force traveling at 100 feet per second or faster and producing droplets with diameters of less than 1 millimeter.

area of convergence
The area on a two-dimensional plane where lines traced through the long axis of several individual bloodstains meet. This approximates the two-dimensional place from which the bloodstains were projected.

area of origin
The location in three-dimensional space that blood that produced a bloodstain originated from. The location of the area of convergence and the angle of impact for each bloodstain is used to approximate this area.

AREA OF CONVERGENCE The area of convergence is the point on a two-dimensional plane from which the drops originated. This can be established by drawing straight lines through the long axis of several individual bloodstains, following the line of their tails. The intersection of these lines is the area of convergence, and the approximate point of origin will be on a line straight out from this area. Figure 10-6 illustrates how to draw lines to find an area of convergence.

An object hitting a source of blood numerous times will never produce exactly the same pattern each time. One can therefore determine the number of impacts by drawing the area of convergence for groups of stains from separate impacts.

AREA OF ORIGIN It may also be important to determine the area of origin of a bloodstain pattern, the area in a three-dimensional space from which the blood was projected. This will show the position of the victim or suspect in space when the stain-producing event took place. The distribution of the droplets in an impact pattern gives a general idea of the distance from the blood source to the bloodstained surface. Impact patterns produced at a distance close to the surface will appear as clustered stains. As the distance from the surface increases, so do the distribution and distance between droplets.

A common method for determining the area of origin at the crime scene is called the *string method*. Figure 10-7 illustrates the steps in the string method:

1. Find the area of convergence for the stain pattern.
2. Place a pole or stand as an axis coming from the area of convergence.
3. Attach one end of a string next to each droplet. Place a protractor next to each droplet and lift the string until it lines up with the determined angle

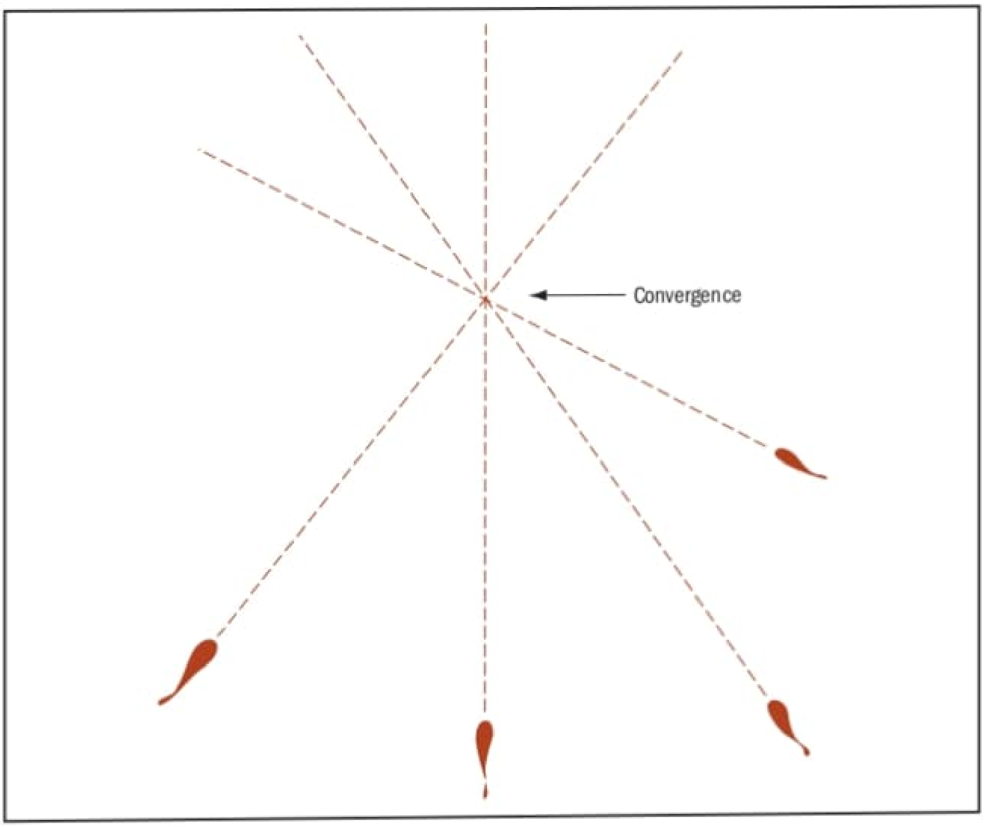


FIGURE 10-6 An illustration of stain convergence on a two-dimensional plane. Convergence represents the area from which the stains emanated. *Courtesy Judith Bunker, J.L. Bunker & Assoc., Ocoee, FL*

CAST-OFF SPATTER

A **cast-off** pattern is created when a blood-covered object flings blood in an arc onto a nearby surface. This kind of pattern commonly occurs when a person pulls a bloody fist or weapon back between delivering blows to a victim (see Figure 10-5 [b]). The bloodstain tails will point in the direction that the object was moving.

cast-off
A bloodstain pattern that is created when blood is flung from a blood-bearing object in motion onto a surface.

The width of the cast-off pattern created by a bloody object may help suggest the kind of object produced by the pattern. The sizes of the drops are directly related to the size of the point from which they were propelled. Drops propelled from a small or pointed surface will be smaller and the pattern more linear; drops propelled from a large or blunt surface will be larger and the pattern wide. The volume of blood deposited on an object from the source also affects the size and number of droplets in the cast-off pattern. The less blood on the object, the smaller the stains produced. The pattern may also suggest whether the blow that caused the pattern was directed from right to left or left to right. The pattern will point in the direction of the backward thrust, which will be opposite the direction of the blow. This could suggest which hand the assailant used to deliver the blows.

Cast-off patterns may also show the *minimum* number of blows delivered to a victim. Each blow should be marked by an upward-and-downward or forward-and-backward arc pattern (see Figure 10-10). By counting and pairing the patterns, one

FIGURE 10-10 The cast-off pattern created from one backward and one forward motion of an overhand swing. Larger drops are deposited in the motion away from the victim because they're made when the weapon holds the greatest amount of blood. The smaller spatters are directed toward the victim. *Bloodstain Pattern Evidence* by A. Y. Wonder, p. 295. Copyright Elsevier, 2007.

can estimate the minimum number of blows. An investigator should take into consideration that the first blow would only cause blood to pool to the area; it would not produce a cast-off pattern. Also, some blows may not come into contact with blood and therefore will not produce a pattern. The medical examiner is in the best position to estimate the number of blows a victim received.

FIGURE 10-11 Arterial spray spatter found at a crime scene where a victim suffered injury to an artery. Courtesy Norman H. Reeves, *Bloodstain Pattern Analysis*, Tucson, AZ, *www.bloody1.com*

ARTERIAL SPRAY SPATTER

Arterial spray spatter is created when a victim suffers an injury to a main artery or the heart. The pressure of the continuing pumping of blood causes blood to spurt out of the injured area (see Figure 10-5 [c]). Commonly, the pattern shows large spurted stains for each time the heart pumps. Some radial spikes, satellite spatter, or flow patterns may be evident because of the large volume of blood being expelled with each spurt. Drops may also be seen on the surface in fairly uniform size and shape and in parallel arrangement (see Figure 10-11).

The lineup of the stains shows the victim's movement. Any vertical arcs or waves in the line show fluctuations in blood pressure. The larger arterial stains are at the end of the overall pattern. The site of the initial injury to the artery can be found where the pattern begins with the biggest spurt. Arterial patterns can also be differentiated because the oxygenated blood spurting from the artery tends to be a brighter red color than blood expelled from impact wounds.

arterial spray
A characteristic bloodstain pattern caused by spurts that resulted from blood exiting under pressure from an arterial injury.

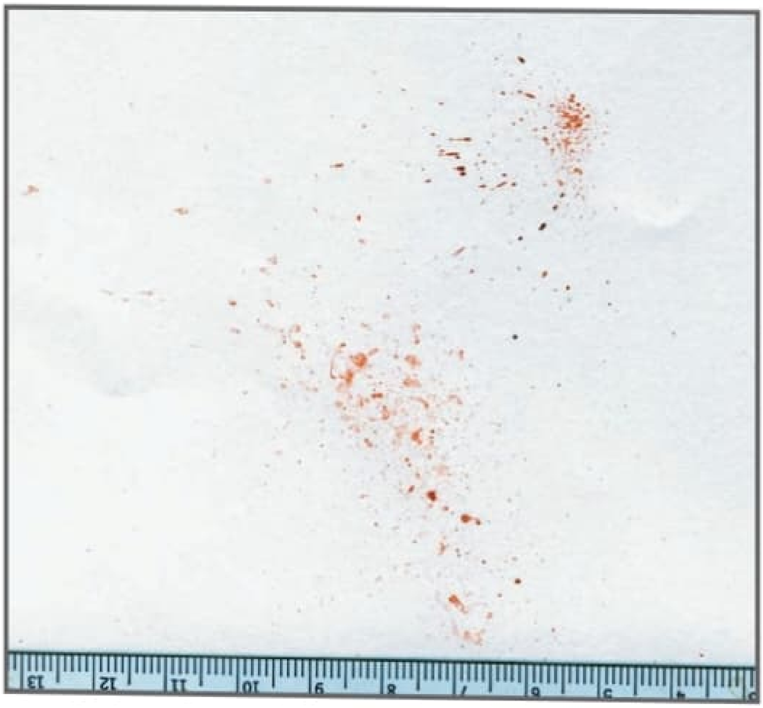


FIGURE 10-12 An example of expirated blood expelled with two wheezes from the mouth *Courtesy, A.Y. Wonde*

EXPIRATED BLOOD PATTERNS

A pattern created by blood that is expelled from the mouth or nose from an internal injury is called an **expirated blood pattern**. If the blood that creates such a pattern is under great pressure, it produces very fine high-velocity spatter. Expirated blood at very low velocities produces a stain cluster with irregular edges (see Figure 10-12). The presence of bubbles of oxygen in the drying drops can differentiate a pattern created by expirated blood from other types of bloodstains. Expirated blood also may be lighter in color than impact spatter as a result of being diluted by saliva. The presence of expirated blood gives an important clue to the injuries suffered and the events that took place at a crime scene.

VOID PATTERNS

A **void** is created when an object blocks the deposition of blood spatter onto a surface or object (see Figure 10-13). The

FIGURE 10-13 A void pattern is found behind a door where the surface of the door blocked the deposition of spatter on that area. This void, and the presence of spatter on the door, shows that the door was open when the spatter was deposited. Courtesy Norman H. Reeves, *Bloodstain Pattern Analysis*, Tucson, AZ, *www.bloody1.com*

spatter is deposited onto the object or person instead. The blank space on the surface or object may give a clue to the size and shape of the missing object or person. Once the object or person is found, the missing piece of the pattern should fit in, much like a puzzle piece, with the rest of the pattern. Voids may help establish the body position of the victim or assailant at the time of the incident.

expirated blood pattern
A pattern created by blood that is expelled out of the nose, mouth, or respiratory system as a result of air pressure and/or airflow.

CONTACT/TRANSFER PATTERNS

When an object with blood on it touches another object that did not have blood on it, this produces a contact or transfer pattern. Examples of transfers with features include fingerprints (see Figure 10-14), handprints, footprints, footwear prints, tool prints, and fabric prints in blood. These may provide further leads by offering individual characteristics.

The size and general shape of a tool may be seen in a simple transfer. This can lead to narrowing the possible tools by class characteristics. A transfer that shows a very individualistic feature may help point to the tool that made the pattern.

Simple transfer patterns are produced when the bloody object makes contact with a surface and the object is removed without any further movement. Other transfers known as *swipe patterns* may be caused by movement of the bloody object across a surface. Generally, the pattern will lighten and "feather" as the pattern moves away from the initial contact point (see Figure 10-15). However, because "feathering" is also a function of the amount of

FIGURE 10-14 A transfer pattern consisting of bloody fingerprints with apparent ridge detail. *Courtesy Lawrence A. Presley, Arcadia University*

transfer pattern
A bloodstain pattern created when a surface that carries wet blood comes into contact with a second surface. Recognizable imprints of all or a portion of the original surface or the direction of movement may be observed.

FIGURE 10-15 A series of swipe patterns moving from right to left. *Courtesy, A.Y. Wonder*

FLOWS

Patterns made by drops or large amounts of blood flowing with the pull of gravity are called flows. Flows may be formed by single drops or large volumes of blood coming from an actively bleeding wound or blood deposited on a surface, from an arterial spurt, for example. Clotting of the blood's solid parts may occur when a flow extends onto an absorbent surface.

flow
A bloodstain pattern formed by the movement of small or large amounts of blood as a result of gravity's pull.

The flow direction may show movements of objects or bodies while the flow was still in progress or after the blood had dried. Figure 10-16 illustrates a situation in which movement of the surface while the flow was still in progress led to a specific pattern.

Interruption of a flow pattern may be helpful in assessing the sequence and passage of time between the flow and its interruption. If a flow found on an object or body does not appear to be consistent with the direction of gravity, one may surmise that the object or body was moved after the blood had dried.

FIGURE 10-16 The flow pattern suggests that the victim was upright and then fell while blood flowed. The assailant claimed the victim was stabbed while sleeping. *Courtesy, A.Y. Wonde*

POOLS

A pool of blood occurs when blood collects in a level (not sloped) and undisturbed place. Blood that pools on an absorbent surface may be absorbed throughout the surface and diffuse, creating a pattern larger than the original pool. This often occurs to pools on beds or sofas.

The approximate drying time of a pool of blood is related to the environmental condition of the scene. By experimentation, an analyst may be able to reasonably estimate the drying times of stains of different sizes. Small and large pools of blood can be helpful in reconstruction because they can be analyzed to estimate the amount of time that has elapsed since the blood was deposited. Considering the drying time of a blood pool can yield information about the timing of events that accompanied the incident.

skeletonization
The process by which the edges of a bloodstain dry to the surface in a specific period of time (dependent on environmental and surface conditions). Skeletonization will remain apparent even after the rest of the bloodstain has been disturbed from its original position.

The edges of a stain will dry to the surface, producing a phenomenon called skeletonization (see Figure 10-17). This usually occurs within 50 seconds of deposition for droplets, and it takes longer for larger volumes of blood. If the

DROP TRAIL PATTERNS

drop trail pattern
A pattern of bloodstains formed by the dripping of blood off a moving surface or person in a recognizable pathway separate from other patterns.

A **drop trail pattern** is a series of drops that is separate from other patterns, and it is formed by blood dripping off an object or injury. The stains form a kind of line, usually the path made by the suspect after injuring or killing the victim. It may simply show movement, lead to a discarded weapon, or provide identification of the suspect if it is made from his or her own blood. Investigators often see this type of pattern in stabbings during which the criminal inadventently cuts him- or herself as a result of using the force necessary to stab the victim. Figure 10-18 shows a drop trail pattern away from the center of action at a crime scene.

The shape of the stains in a drop trail pattern can help investigators determine the direction and speed at which a person was moving. The tails of the drops in a trail pattern point in the direction the person was moving. More circular stains are found where the person was moving slowly. This information may be helpful in reconstruction.

Documenting Bloodstain Pattern Evidence

Blood spatter patterns of any kind can provide a great deal of information about the events that took place at a crime scene. For this reason, investigators should note, study, and photograph each pattern and drop. This must be done to accurately record the location of specific patterns and to distinguish the stains from which laboratory samples were taken. The photographs and sketches can also point out specific stains used in determining the direction of force, angle of impact, and area of origin.

Just as in general crime-scene photography, the investigator should create photographs and sketches of the overall pattern to show the orientation of the pattern to the scene. The medium-range documentation should include pictures and sketches of the whole pattern and the relationships between individual stains within the pattern. The close-up photographs and sketches should show the dimensions of each individual stain. Close-up photographs should be taken with a scale of some kind showing in the photograph.

Two common methods of documenting bloodstain patterns place attention on the scale of the patterns. The *grid method* involves setting up a grid of squares of known dimensions over the entire pattern using string and stakes (see Figure 10-19). All overall, medium-range, and close-up photographs are taken with and without the grid. The second method, called the *perimeter ruler method*, involves setting up a rectangular border of rulers around the pattern and then placing a small ruler next to each stain. In this method, the large rulers show scale in the overall and medium-range photos, whereas the small rulers show scale in the close-up photographs (see Figure 10-20). Some investigation teams use tags in close-up photographs to show evidence numbers or other details.

An area-of-origin determination may be calculated at the discretion of the bloodstain analyst when the circumstances of the case warrant such a determination.

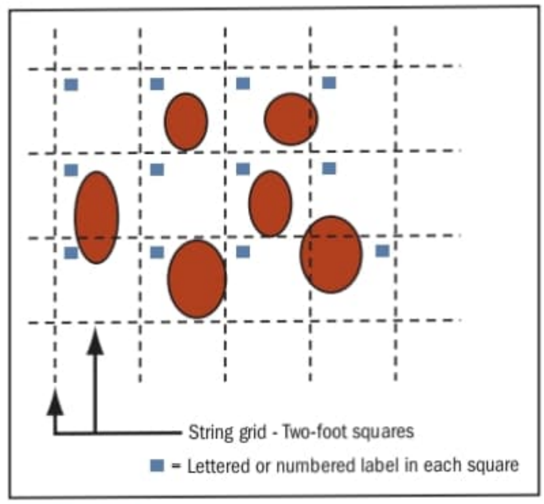


FIGURE 10-19 The grid method may be used for photographing bloodstain pattern evidence. *Crime Scene Investigation & Reconstruction*, 3rd ed., by R.R. Ogle, Jr. (Upper Saddle River, NJ: Prentice-Hall, 2011).

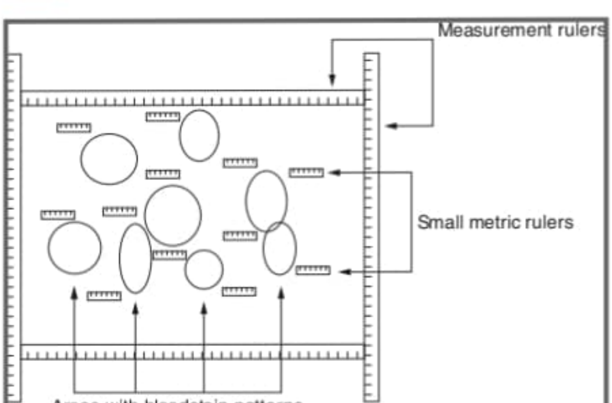


FIGURE 10-20 The perimeter ruler method may be used for photographing bloodstain pattern evidence. *Crime Scene Investigation & Reconstruction*, 3rd ed., by R.R. Ogle, Jr. (Upper Saddle River, NJ: Prentice-Hall, 2011).

Virtual Lab
Blood Spatter Evidence
To perform a virtual blood spatter analysis, go to
www.pearsoncustom.com/us/vlm/

All measurements of stains and calculations of angle of impact and point of origin should be recorded in crime-scene notes. Especially important stains can be roughly sketched within the notes.

Only some jurisdictions have a specialist on staff to decipher patterns either at the scene or from photographs at the lab. Therefore, it is important that all personnel be familiar with patterns to properly record and document them for use in reconstruction.

Quick Review

- Photographs and sketches should first be created of the overall bloodstain pattern to show the orientation of the pattern to the scene.
- Medium-range and close-up photographs may use the grid method or perimeter ruler method to show the orientation and relative size of the pattern and individual stains.

2.4 Analyzing Spatter Stains

A *spatter stain*, based on the recommended terminology of the Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN), is "a bloodstain resulting from a blood drop dispersed through the air due to an external force applied to a source of liquid blood." The patterns of spatter stains, including the shape and the size of the stains, are affected by the direction and the angle of impact (discussed in detail in Section 2.5.3) of the spatter stains that are projected. This information can be obtained from an analysis of the patterns of the spatter stains. Thus, it is possible to determine the area of origin (discussed in detail in Section 2.4.4) where an external force was directly applied to the blood source.

2.4.1 Velocity of Blood Droplets

The sizes of bloodstains are affected by the external force that is directly applied on a blood source. Increasing the energy of the external force will reduce the surface tension, thus decreasing the size of the droplets. Since these travelling blood droplets are driven by the energy derived from the external force, the higher the energy, the higher the velocities of the droplets. Bloodstains can be divided into three categories based on different travelling speeds. Low-velocity impact spatter is formed when a blood droplet is travelling at <1.5 m/s. The resulting stains are usually >4 mm in diameter (Figure 2.5a). As the travelling speed of blood droplets increases, the size of the spatter stain decreases. Medium-velocity impact spatter is formed when a blood source is subjected to a force associated with beatings or stabbings. The resulting stains range from 1 to 4 mm in diameter (Figure 2.5b). High-velocity impact spatter is formed when a blood source is subjected to a force associated with shooting using firearms. The resulting stains are usually <1 mm in diameter.

2.4.2 Determining the Directionality of the Stains

In this analysis, the effects of the directionality of the spatter stains projected are examined. SWGSTAIN defines the directionality to be "the characteristic of a bloodstain that indicates the direction blood was moving at the time of deposition." This analysis is applicable when the blood source is projected onto a surface at an angle of between 0° and 90°. Under this condition, the resulting spatter stain is an elongated ellipse (Figure 2.6), which is known as the *parent stain*. Additionally, *satellite stains* in the vicinity of the parent stain can be observed. As defined by SWGSTAIN, a satellite stain is "a smaller bloodstain that originated during the formation of the parent stain as a result of blood impacting a surface." More importantly, a spine is observed, which is the pointed edge away from the parent stain. When such a pattern is observed, the pointed end of the spine always points toward the direction of travel of the bloodstains.

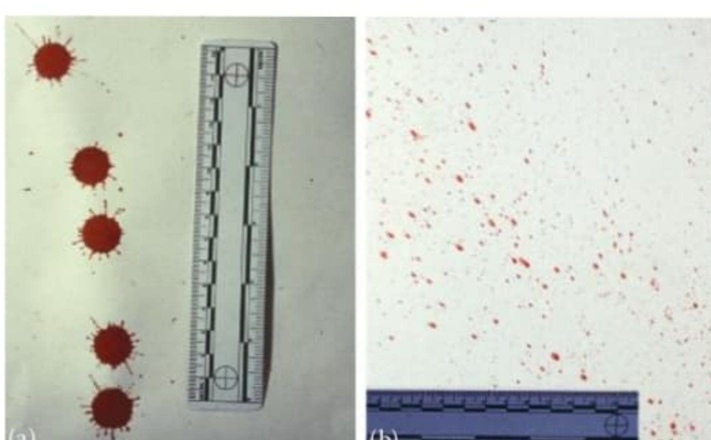


Figure 2.5 Bloodstains can be categorized based on their travelling velocities. (a) An example of a low-velocity impact spatter stain and (b) an example of a medium-velocity impact spatter stain. (© Richard C. Li.)

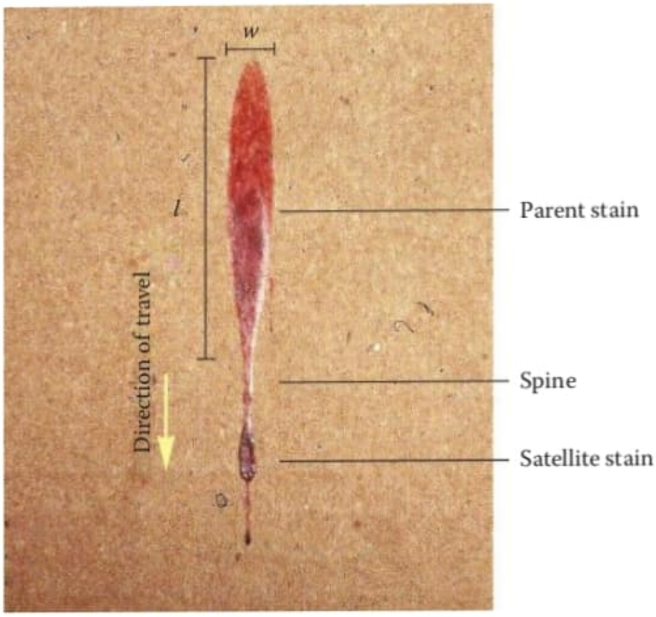


Figure 2.6 The morphology and directionality of a blood spatter stain. The arrow indicates the direction of travel. (© Richard C. Li.)

2.4.3 Determining Angles of Impact

SWGSTAIN defines the *angles of impact* to be "the acute angle (alpha), relative to the plane of a target at which a blood drop strikes the target." The shapes of the spatter stains are affected by the angle of impact. When a blood drop lands on a surface at a perpendicular angle (90°), a circular parent stain is formed (Figure 2.7), where the length and the width of the stain are equal. When a blood drop is projected onto a surface at an angle of between 0° and 90°, the stain is elongated. As the impact angle decreases, the shape of the spatter stain is more elongated (Figure 2.7), in which the length of the stain is greater than the width. It is observed that the ratio of the width and the length of the parent stain is proportional to the sine of the impact angle, which is summarized in the following trigonometric equation:

$$\sin \alpha = \frac{w}{l}$$

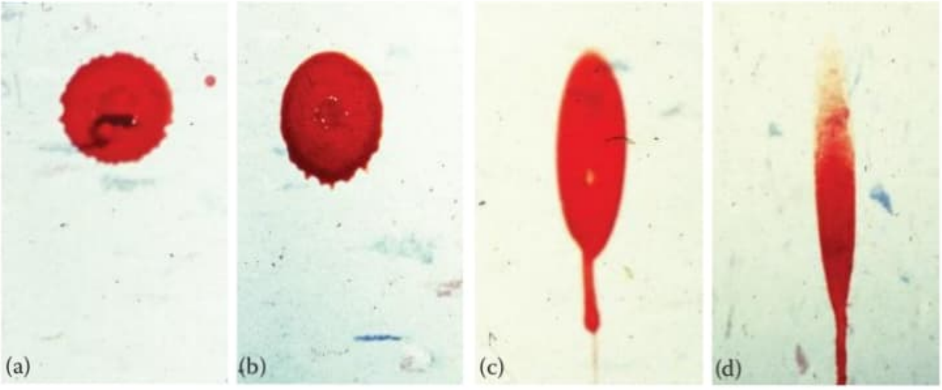


Figure 2.7 The effects of the impact angle on the shapes of blood spatter stains. Spatter stains are projected onto the surface of a ceramic tile at: (a) 90°, (b) 50°, (c) 20°, and (d) 10°. (© Richard C. Li.)

2.4.4 Determining Area of Origin

SWGSTAIN defines the *area of origin* to be "the three-dimensional location from which spatter originated." Using simple trigonometry, the area of origin can be determined based on the measurements from multiple elongated spatter stains (Figure 2.9). This can be accomplished by using the string method or the tangent method.

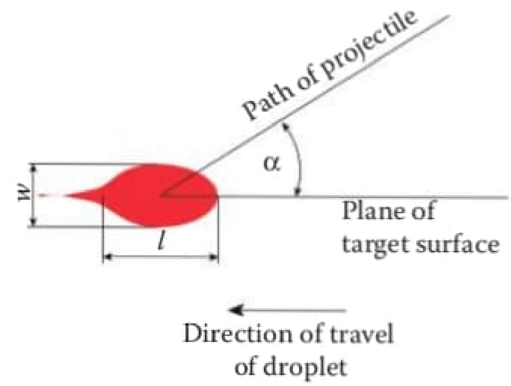
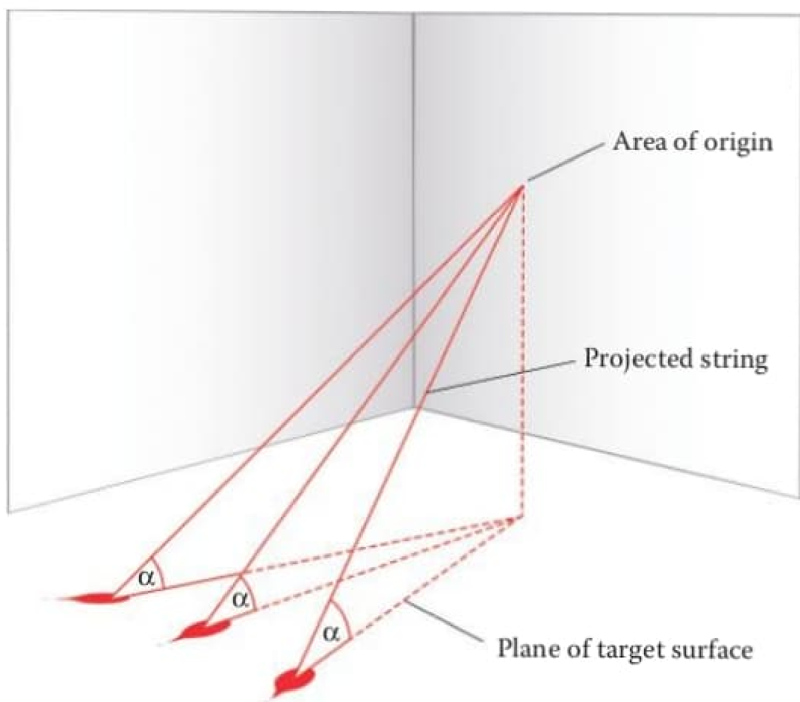


Figure 2.8 Impact angle. The angle between the path of a projectile and the plane of the target surface is shown. α, the impact angle; *l*, the length of the parent stain; and *w*, the width of the parent stain. (© Richard C. Li.)



2.5 Types of Bloodstain Patterns

Bloodstain patterns can be classified into three basic categories: passive, transfer, and projected bloodstains.

2.5.1 Passive Bloodstains

A *passive bloodstain* is formed due to bleeding from wounds, and the blood is deposited on a surface by the influence of the force of gravity alone. For example, a *drip stain* is formed when a falling drop of blood from an exposed wound or a blood-bearing object lands on a surface. If a blood source is moving, a *drip trail* is formed. A *drip pattern*, which is distinct from a drip stain, is formed when a liquid drips into another liquid, where one or both of the liquids are blood (Figure 2.13). As a result, secondary spatter stains are generated. As the dropping distance of the blood increases, the number of secondary spatter stains usually increases, and the size of these stains decreases. An approximate estimation of the dropping distance is possible. A *splash pattern* is formed when a volume of blood spills onto a surface (Figure 2.14). Splash patterns usually

Figure 2.13 A drip pattern. The secondary spatter stains are shown. (© Richard C. Li.)

Figure 2.14 A splash pattern. Peripheral, elongated bloodstains are shown. (© Richard C. Li.)

have large stains surrounded by numerous, peripheral, elongated bloodstains. A *flow pattern* is caused by the movement of a large volume of blood on a surface either due to gravity or to the movement of the target such as a victim or postmortem disturbance. A *pool* is a bloodstain resulting from the accumulation of liquid blood on a surface (Figure 2.15). Sometimes, air bubbles in the blood may cause a *bubble ring* pattern (Figure 2.15). If blood is coagulated, gelatinous *blood clots* can be observed. Additionally, a *serum stain*, which consists of the liquid portion of the blood after a clot is formed, may also be present.

2.5.2 Transfer Bloodstains

A *transfer bloodstain*, based on SWGSTAIN, is "a bloodstain resulting from contact between a blood-bearing surface and another surface." For example, a *swipe pattern* is "a bloodstain pattern resulting from the transfer of blood from a blood-bearing surface onto another surface, with characteristics that indicate relative motion between the two surfaces." For example, bloody impressions can provide information about the shape, the size, and the pattern of the objects such as finger ridges, hands, and shoe soles. Examples of hand and shoe swipe patterns are shown in Figures 2.16 and 2.17. A *wipe pattern* is "an altered bloodstain pattern resulting from an object moving through a preexisting wet bloodstain." Examples of wipe patterns are shown in Figures 2.18 and 2.19. A *perimeter* stain, a type of wipe pattern, is a bloodstain that is disturbed before it is dried but it maintains the peripheral characteristics of the original stain (Figure 2.20). Perimeter stain patterns can be useful for the estimation of sequential events of acts. The pattern can also be used to estimate a time frame between the time of bleeding and the subsequent act. However, the drying time of a blood drop varies based on the surrounding conditions. Therefore, it is necessary to carry out a crime scene reconstruction under similar conditions to those of the scene to make such estimations.