Bloodstain Pattern Analysis

Third Edition

With an Introduction to Crime Scene Reconstruction

Tom Bevel
Ross M. Gardner

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Practical Aspects of Criminal and Forensic Investigations Series

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Third Edition

With an Introduction to Crime Scene Reconstruction

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Editor's Note

This textbook is part of a series entitled "Practical Aspects of Criminal and Forensic Investigations." This series was created by Vernon J. Geberth, New York City Police Department Lieutenant Commander (Ret.), who is an author, educator, and consultant on homicide and forensic investigations.

This series has been designed to provide contemporary, comprehensive, and pragmatic information to the practitioner involved in criminal and forensic investigations by authors who are nationally recognized experts in their respective fields.

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Foreword

***Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction* Third Edition** in full-color by Tom Bevel and Ross M. Gardner is long overdue. This completely revised and enhanced edition is a practical and concisely written text. It is the most complete and comprehensive handbook to date from the perspective of the criminal investigator and forensic scientist on the subject of bloodstain spatter analysis.

The authors have provided the reader with an eloquent and practical guide for the analysis of bloodstain patterns and crime scene reconstruction based on many years of practical experience. Their original lab manual published over 24 years ago was entitled "*Bloodstain Pattern Analysis: Theory and Practice.*" This manual eventually became the framework for the first edition of ***Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction,*** which challenged some of the subjective interpretation systems of bloodstain pattern assessments.

This new edition is based on a true taxonomy. The future of bloodstain pattern analysis will be based on description. Building on well-established classifications ideas in bloodstain pattern analysis **(BPA)** the authors have refined an objective classification system based on a taxonomic approach. ***Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction* Third Edition** is the basis for standardization of blood spatter analysis and establishes the need for universal rules that define this discipline by stressing the underlying scientific basis and how best to objectively apply this knowledge to cases in the field.

Ross Gardner first brought the idea of taxonomy to the attention of the SWGSTAIN GROUP in 2002. Bevel and Gardner introduce a new Chapter 3 to clarify and present a taxonomic classification system, which clearly describes the characteristics of different patterns. A taxonomy is simply a defined set of rules for classification. It establishes criteria against which the analyst can compare the scene stains to. The idea of taxonomy is derived from biology where organisms are classified by shared characteristics. These characteristics create a hierarchical relationship between the various groups. Although other authors have previously provided the hierarchy, Bevel and Gardner are the first to clearly describe the supporting characteristics for that hierarchy.

In addition to elucidating the classification system, the authors have included within the text, a full-color foldout of a Bloodstain Pattern Decision Map, which can be used for ready-reference in reaching a classification decision no matter what classification system they use. They also provide a detailed methodology for bloodstain pattern analysis, which is described in Chapter 4

***Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction* Third Edition** provides specific details on Crime Scene Analysis/ Reconstruction in explaining a proven methodology involved in the process. This methodology is built upon scientific method and provides focus and structure to the analyst as they conduct the analysis.

The authors provide an excellent historical perspective to acquaint the reader with the significant chronology of the application of this technique. The authors provide excellent

information on distinguishing crime scene analysis from behavioral analysis and discuss the many considerations involved in the reconstruction of the crime.

***Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction* Third Edition** explains the complex mechanics of blood spatter analysis with a new chapter which addresses the medical examiner and the anatomical issues related to bloodstain pattern analysis, which includes a discussion of blood and the circulatory system and the nature of bleeding associated with various traumatic and non-traumatic injuries. Other new chapters include bloodstain pattern analysis associated with clothing and fabric issues as well as a chapter that describes presumptive testing in detail. All of the existing chapters have been revised and updated to address taxonomy.

The most significant improvement in this third edition with the exception of the revised chapters is the inclusion of almost 400 photographs, three hundred and seventy of which are in full-color, which graphically illustrate the dynamics of bloodstain pattern analysis.

The authors bring over 50 years of practical experience to this text especially with their respective backgrounds in actual criminal investigations. Tom Bevel, my friend and colleague for many years, is a retired police captain from Oklahoma City, Oklahoma. Tom Bevel is the owner of TBI, LLC a forensic education and consulting company. He is also an adjunct professor in the Masters of Forensic Science program at the University of Central Oklahoma. Captain Bevel (Ret.) holds a master's degree in Criminal Justice and has extensive training in the area of criminal investigation both in the United States and Europe. Tom Bevel has numerous professional affiliations including; The Association for Crime Scene Reconstruction (ACSR, a distinguished member of the International Association of Bloodstain Pattern Analysts (IABPA), and the American Academy of Forensic Sciences. Tom has acted as a police consultant in over forty-six different states and eleven foreign countries. He has personally participated in more than 3300 criminal investigations in which bloodstain spatter evidence was the issue and has testified in numerous trials as an expert witness.

Ross M. Gardner, served for The United States Army Criminal Investigation Command (USACIDC) for over twenty-four years as a felony criminal investigator, served four years as a chief of police for a small suburban Atlanta police department.

He retired from public service in 2003. He holds a Master's Degree in Computer and Information Resource Management and has extensive training in the area of criminal investigation through the United States Military. He served as an adjunct professor for Central Texas College in the Police Science program. He is also certified as a senior crime scene analyst with the International Association of Identification and has published as a recognized expert in the field of bloodstain pattern analysis. Special Agent (Ret.) Gardner, who now consults in crime scene analysis, bloodstain pattern analysis and crime scene investigation, also has also has numerous professional affiliations.

He is the former president of the Rocky Mountain Association of Bloodstain Pattern Analysts (RMABPA) as well as the Association for Crime Scene Reconstruction (ACSR) and served as chairman of the education committee for both the RMABPA and the International Association of Bloodstain Pattern Analysts (IABPA).

In my textbook ***Practical Homicide Investigation: Tactics, Procedures, and Forensic Techniques Fourth Edition,*** I point out that; "Solving homicides, especially those without witnesses are extremely more difficult to solve because your main witness, the deceased, is dead. One must develop the ability to "absorb" the crime scene, and be able to read the uncollectible nuances of the event." The classification and analysis of bloodstain patterns

within the crime scene oftentimes provides the investigator with the critical information to reconstruct the crime. Used properly, bloodstain pattern analysis can help establish specific events associated with the crime.

I personally believe that without practical scene experience there is a deficiency in crime scene reconstruction. Seasoned practice necessitates that the practitioner have that ability to "absorb" the crime scene, and be able to read the uncollectible nuances of the event. This is what we refer to as "scene experience" as opposed to a strict "laboratory" mentality. Tom Bevel and Ross Gardner both have this "scene experience" as well as the necessary knowledge to evaluate and apply the scientific methodology to the reconstruction process.

***Bloodstain Pattern Analysis with an Introduction to Crime Scene Reconstruction* Third Edition** is a masterful blend of "Practice and Theory" with practical crime scene knowledge and the application of scientific methodology to the process of crime scene reconstruction. The new edition follows a logical path throughout the text, highlighted with excellent color examples starting with an explanation of what bloodstain pattern analysis is, the terms used, the basic classifications, a methodology for BPA and then a discussion of the various skills utilized in BPA. It is organized in such a manner to allow the reader quick and easy references into specific areas of blood spatter which includes the full-color foldout of the Bloodstain Pattern Decision Map.

Vernon J. Geberth, M.S., M.P.S.
Author of Practical Homicide Investigation
Series Editor

Preface

The goal of forensics and crime scene reconstruction is simply to seek the truth. The analyst has no other agenda. In pursuing this end, we revisit what we hope is a not too distant past and attempt to recreate the events that unfolded. This task is anything but simple and the tools employed are all of the forensic disciplines.

Each area of forensics provides insight and a glimpse back into this past. Each has its place in evaluating the aftermath of crime — the physical evidence. In the most classical sense, the majority of the forensic disciplines provide us knowledge as to the "who" of crime. Fingerprints, serology, and trace and fiber evidence all give us the ability to associate people or objects with a crime scene. Forensic pathology, on the other hand, has always been a primary link to the "what" of crime, providing insight to some of the events that occurred during the incident.

Bloodstain pattern analysis is a discipline that serves a significant role in answering the question of "what" happened. Used properly, bloodstain pattern analysis helps establish specific events associated with violent crimes. In this capacity, bloodstain pattern analysis acts as a critical bridge between classical forensics and crime scene reconstruction.

Although certainly not a young discipline, bloodstain pattern analysis is just beginning to recognize some of the universal rules that define it. We still see aggressive discussions between analysts over what they can or cannot infer from a specific stain. More often than not, these arguments consume our objectivity. These arguments lead us to a darker side of forensics, where subjective analysis reigns. To fight this tendency, our continuing goal must be to understand the discipline, its underlying scientific basis, and how best to objectively apply this knowledge to cases in the field. The investigator's mission is to always illuminate the truth, not shroud it in shadows.

The authors of this book come to you from two distinctly different backgrounds, though both have a high level of experience in "on scene" crime scene evaluation. One is a career civilian law enforcement officer, and the other is a retired criminal investigator for the U.S. Army. Both are nationally and internationally respected in their fields. Two very different roads led them to the same destination. Interestingly enough, those roads crossed outside the city of London, at the Metropolitan Police Detective Training School. There both authors, although several years apart, attended the Scenes of Crimes Officer (SOCO) Course.

The British approach to scenes of crime is, at the very least, one of the most methodical in the world. The SOCO course teaches the students to understand and incorporate all forensic evidence in the evaluation of crime. It places responsibility for understanding the interrelationship of that evidence on none other than a generalist, the crime scene investigator.

Perhaps then it is the SOCO course that serves as the wellspring of the authors' shared passion and belief: conduct crime scene evaluations using a holistic approach. Inherent in this thought is that case resolution is critically dependent upon proper crime scene analysis. However, case resolution is not just a matter of proving someone guilty. The investigator

seeks to establish the truth, no matter what it may be. This demands a consideration of all evidence available, and the correlation of such evidence in an attempt to identify reasons for contradictory results when they happen to occur. Crime scene reconstruction as a discipline offers an avenue to this goal. Crime scene reconstruction (or crime scene analysis) provides proven methodologies that allow objective snapshots of the crime to be established, and in many instances, sequenced. This information, although not defining an absolute truth, is always effective for helping the criminal justice system define its concept of what that "truth" may be.

In the criminal justice system, it is not uncommon to encounter a lawyer who adamantly believes, no matter what the nature of the testimony, that the investigator established in his or her own mind the innocence or guilt of a subject before completing the crime scene evaluation. It appears incomprehensible to counsel that the investigator can take the often subjective information reported and conduct an objective investigation. Such a reaction should not surprise us because the idea of objectivity is relatively foreign to trial law. No matter what the underlying truth, lawyers (both the prosecution and defense) highlight the information that best serves their position, and attempt to diminish or ignore that which works against them. Law professors refer to science as a smorgasbord, where the lawyers can step up to the table and take from science what they want. Anything that looks unappetizing is simply ignored. This is the actual mindset of those who claim criminal investigators are subjective!

The crime scene analyst, however, can ill afford to pursue his or her end with the same mindset. Choosing what evidence one will or will not consider in the analysis is heresy. Unfortunately, that trap is far too easy to fall into.

Within the scene lies the evidence, which, if properly analyzed, provides everyone with an ability to define specific facts and certainly infer others. Based on the totality of this information, it may well be possible to determine the most probable events surrounding the situation. Even if unable to define the overall event, proper analysis still allows for the elimination of certain events, which alone adds clarity.

No single forensic discipline has the potential to provide as much clarity regarding the occurrences at a crime scene as does bloodstain pattern analysis. However, that cannot lead to an expectation that the bloodstain evidence will stand alone. But in the right hands, bloodstain pattern analysis is an extremely effective tool for defining the truth.

Bloodstain pattern analysis and crime scene analysis are not for the casual investigator who intends only to graze the surface, find a quick answer, and move on. The bloodstain pattern analyst is truly one who reconstructs crime scenes. As such, he or she must understand all of the forensic disciplines. The analyst must be able to objectively apply each category of evidence to the situation, inferring as little as possible, but recognizing the whole. In order to accomplish this task the bloodstain pattern analyst must also understand and apply proven crime scene analysis methods. In that fashion, the evidence establishes a knowledge base from which the analyst reaches the "truth."

In this third edition, we have significantly expanded the discussions of both bloodstain pattern analysis and crime scene analysis. Included are proven, practical, detailed methodologies to apply in the field for each discipline. We hope the student and practitioner find this book a single source document that can aid in teaching these disciplines or in maintaining or enhancing the practitioner's skills.

As we stated in previous editions, the business of investigations and forensics is about defining truth as effectively and objectively as possible. In part, the oath of office for a U.S. Army Criminal Investigation Special Agent states: "I shall at all time seek diligently to discover the truth, deterred neither by fear nor prejudice..." We dedicate this newest edition to everyone, analysts and investigators alike, who recognizes and understands the importance of their roles as objective truth seekers.

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In considering a project of this nature, the effort of the authors alone rarely ensures success. We would like to offer thanks and acknowledgment to the following individuals for their support and efforts:

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There are many more individuals who may not be named here. All have contributed to this discipline in some fashion, which in turn assisted in the writing of this book. We salute them for their individual effort, insightfulness, and resulting research in support of bloodstain pattern analysis and crime scene reconstruction.

Please note. Solely for the purpose of readability, we used male references throughout the book. In no way should this be construed by the reader as ignoring the many female analysts in our profession.

Introduction

Bloodstain pattern analysis and crime scene reconstruction are distinct forensic disciplines. Bloodstain pattern analysis seeks to define "what" caused the bloodstains in the scene. In pursuing this end, the bloodstain pattern analysts cannot help but reconstruct crime. Crime scene reconstruction, also referred to as crime scene analysis, seeks to establish all of the actions associated with the crime or incident in question and, when possible, to order those actions. Thus, crime scene reconstruction is concerned with the "what" of crime as well.

The purposes of both disciplines are so intertwined that it is often difficult to see a distinction between them and, as we will see, the two disciplines share clearly common threads and methodologies.

Crime scene reconstruction demands that we evaluate all physical evidence to derive some conclusion as to what occurred. As Geberth reminds us, for homicide investigations, case resolution hinges on "*careful and intelligent* [italics added] examination of the scene."[1] Much as a reporter does, the criminal investigator attempts to define the who, what, when, where, how, and why of a crime to assist in understanding what really happened. There is an unfortunate problem associated with this process: there is no standard by which we can test our ultimate conclusions. An archaeologist once made an analogy about this difficulty — discussing a dig and the conclusions drawn from it, he said, "It's something like putting together a jigsaw puzzle without having access to the box. You really don't know what the picture is supposed to look like."[2]

The crime scene investigator shares the archeologist's dilemma, because the investigator's box top is not available either. Despite this limitation, crime scene analysis attempts to define the nature of actions that are so dynamic that even if we had a videotape of the incident, they might not be fully understood. It should not be surprising that we share in the archeologist's dilemma, for, as we will explain, archeology and crime scene analysis also share common purposes and methodologies. We will call upon some of the established principles of archeology to help define crime scene reconstruction methodologies.

The crime scene analyst's primary goal is to identify those actions that make up the crime or incident being evaluated, as well as the order of those events. Thus, identifying specific actions associated with the crime, i.e., the "what" of a crime, is of significant concern.

In their most classic use, the majority of forensic disciplines provide the investigator with information regarding the "who" of the crime. Blood typing, DNA evaluations, fingerprint evidence, and hair examinations help us decide who was or was not present at the scene. In this concept of who, we also include areas such as forensic chemistry, biology, geology, and trace evidence examinations, as they help associate items with our players and with the scene. This, too, ultimately serves the function of defining the "who" of the reconstruction.

Our answers to "what," the actions that occurred during the crime, are sought quite often through the application of forensic pathology. As Dr. James Luke stated, "From the standpoint of forensic pathology, the two major parameters that form the basis of any case investigation are (1) identification and documentation of the postmortem findings present, and (2) interpretation of those findings in the context of the circumstances of death."[3]

In the past few decades, the discipline of bloodstain pattern analysis has reawakened to its role in documenting these circumstances. Bloodstain analysis brings to the investigation the ability to define those events which could or could not have occurred during the course of bloodshed. Once identified, these facts are considered in light of all other evidence as a means of corroborating or refuting statements, confessions, or investigative theories.

Bloodstain pattern analysis in many ways mirrors the role of forensic pathology. Once again quoting Dr. Luke, "It is the responsibility of the forensic pathologist finally to construct a scaffolding of factual information against which witnesses' and suspects' statements can be evaluated."[4] Bloodstain evidence in this role (acting as a scaffolding or part of the lattice) cannot stand apart from other evidence.[5] Reconstruction demands that we consider all evidence. Viewed from a holistic approach, all the evidence available should preferably lead those who view it to a similar conclusion.

This concept of a generally agreed-upon conclusion should not be a foreign thought, particularly when considering bloodstain patterns. They are, after all, graphically oriented. For example, in describing a pattern transfer as "consistent with" something, any analyst should be able to point to some physical characteristic of the stain and then to the correlating item that created it. The analyst should then be able to create some generalized reproduction of the pattern using the item. Having done so, another analyst cannot simply ignore this information. Granted, we may discover a secondary method of stain creation, but this simply adds a responsibility to discover which of the two represents the best explanation. If a stain is observable and reproducible, it is difficult for two analysts to rationally argue their beliefs from mutually exclusive positions. When this occurs, it is very likely the result of subjective analysis on the part of one or both. Unfortunately, subjective analysis in both bloodstain pattern and crime scene analysis is a fact of life. To help preclude subjectivity, the analyst should attempt to achieve several things.

First, the analyst must understand all areas of forensic science and have been directly exposed to crime scenes. Tom Griffin of the Colorado Bureau of Investigation often remarks that analysts need a "scene sense." This sense gives the analyst a more rounded perception, taking into consideration the many subtleties and interrelationships found at scenes. Evidence viewed from the confines of a white-walled laboratory is far too sterile. It leaves the viewer lacking a realistic perspective of crimes and crime scenes. It is this perspective that makes up "scene sense." As the SOCO course at the Hendon Detective Training School teaches, we gain much from viewing evidence *in situ*. This is true not only from a case perspective, but also for the long-term development of the investigator.

Do not construe the necessity for understanding these disciplines as meaning the analyst is an expert in all of them. Far from it, crime scene analysts are generalists. They have, much like a manager, the knowledge to take the experience and expertise of the other team members and put them all together. This process is at the heart of crime scene reconstruction.

Second, analysts must understand their discipline. Bloodstain pattern analysis in particular is far from being a static field. Our understanding changes every day due to research efforts. But as we base bloodstain pattern analysis on the application of physical laws on blood, there are certain universal rules we can apply. These rules are as true today as they were when first observed.

In the third edition, we have introduced three significant additions to bloodstain pattern analysis. First, we have presented a true taxonomic bloodstain pattern classification system in which the criteria that the analyst should judge a bloodstain are written out and (hopefully) clear. With the assistance of Phillipe Esperanza, we have also included a decision

map, which is intended to guide the analyst through that classification process. These two additions are a major step forward, removing the claims of "subjectivity" leveled at bloodstain pattern analysis. The third addition is a practical methodology to employ in bloodstain pattern analysis that follows the scientific method. Once again, this addition should functionally aid every analyst who employs it and help fend off the "subjectivity" attack in court. These three elements are long overdue. The practice of forensics demands we find objective ways to pursue our discipline; each addition serves this function and attempts to pull bloodstain pattern analysis up by its bootstraps into the twenty-first century.

As with bloodstain pattern analysis, there are common themes throughout the history of crime scene reconstruction that guide the analysts in their purpose. Understanding these universal applications and themes, and then seeking those areas that require further study should be the lifetime goal of every analyst. Since 1997, we have taught and refined the methodology known as Event Analysis, which incorporates these basic themes. We have always correlated the archeologist's dilemma to our discipline, and when we turned to literature on archeology we found significant correlations in purpose, which we will discuss.

The interrelationship of these two disciplines places an added burden on the practitioner. Because crime scene reconstruction so often relies on the information developed by the bloodstain pattern analysis, it is imperative that the crime scene analyst have a solid understanding of bloodstain patterns. Just the same, as the bloodstain pattern analysts are engaged in creating a partial reconstruction, they must understand and apply the basic tenets and methodologies of crime scene reconstruction to be effective.

Neither of these disciplines can be taken lightly. The analyst must approach them with a willingness to immerse himself in the history and methodology of both. Neither discipline is for the faint of heart; both demand a level of objectivity, dedication, and significant study. But when these disciplines are applied in an appropriate and acceptable fashion, they provide functional and objective data that will aid juries and judges in seeking justice.

This text will explore the tenets of bloodstain pattern analysis in depth — what it is, how it is used, and practical methodologies to employ in order to achieve defensible results. We will also explore the role of crime scene analysis and reconstruction and its relationship to bloodstain pattern analysis.

We do not pretend to offer the "only" methodologies and techniques for pursuing bloodstain pattern analysis and crime scene analysis, but we will offer proven methodologies and techniques. Applied appropriately, the ideas and practical approaches in this book will guide and focus any investigative effort.

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Bloodstain Pattern Analysis: Its Function and a Historical Perspective

1

> And Cain quarreled with Abel his brother: and it came to pass, when they were in the field, that Cain rose up against Abel his brother, and slew him.
>
> And the Lord said unto Cain, Where is Abel, thy brother? And he said, I know not: Am I my brother's keeper?
>
> And the Lord said, What hast thou done? The voice of thy brother's blood crieth unto me from the ground. And now art thou cursed from the earth, which hath opened her mouth to receive thy brother's blood from thy hand. When thou tillest the ground, it shall not henceforth yield unto thee her strength; and a vagabond shalt thou be on the earth.[1]
>
> **Genesis 4:10**

Reading these passages one might wonder, was God really unaware of what transpired between Cain and Abel? Was He then convinced of the crime only by the presence of Abel's blood? This seems unlikely given the nature of the Judeo-Christian God. Rather, it would appear that God was reminding Cain that no matter what Cain's denial, the physical evidence of the deed spoke in as strong, if not a more convincing, voice. In these few short paragraphs we find what may be the first recorded use of bloodstain pattern analysis in a judicial setting.

The Function of Bloodstain Pattern Analysis

What is the function of bloodstain pattern analysis? Like any forensic discipline, bloodstain pattern analysis seeks to define the facts surrounding some incident that is in question. The examination of the physical nature of bloodstains provides information specific to the events that occurred during the incident.

We often refer to what the analyst evaluates as the "static aftermath" of an event.[2] Dispersion, shape characteristics, volume, pattern, the number and size of bloodstains, and their relationship to the surrounding scene are part of this aftermath. This information provides the investigator with a window into the past, helping define an objective history for a given incident. Clarity is not a guarantee, for it is possible the information present in the bloodstains will fail to illuminate any of the issues in question. Often, however, the analyst finds direct and convincing information that makes the role of the fact finder much easier.

Bloodstain pattern analysis is based on a very simple theory: blood as a fluid (a colloidal fluid, but a fluid nonetheless) will react to external forces in a predictable fashion. The cohesive forces of surface tension and viscosity, the various external forces (e.g., impact, accelerated motion, stream ejection) as well as gravity and air resistance will act together to produce similar results (patterns) under generally similar conditions. Thus, bloodstain patterns are reproducible phenomena. The physical characteristics of the bloodstain pattern help define the general nature of the event that created it. As we will discover, the basic event types that can be differentiated include:

- Blood dispersed from a point/area source by a force (e.g., impact patterns)
- Blood ejected over time from an object in motion (e.g., cast-off patterns)
- Blood ejected in volume under pressure (e.g., spurt and gush patterns)
- Blood dispersed as a function of gravity (e.g., drip, drip trails)
- Blood that accumulates and/or flows on a surface (e.g., pools and flows)
- Blood that is deposited through contact transfer (e.g., smears and pattern transfers)

Additional information we are likely to discover through an examination of the bloodstain patterns includes:

- The direction in which a stain was traveling when deposited
- The angle of impact
- The area of origin (in 3-dimensional space) for impact patterns
- The direction from which a force was applied
- The nature of object(s) involved in creating the pattern
- In some instances, the approximate number of blows struck during an incident
- The relative position(s) in the scene of the suspect, victim, or other related objects during the incident
- Movement of individuals and/or objects during and after bloodshed
- Sequencing of multiple events associated with an incident

The end product of a bloodstain pattern analysis is a series of defined events that occurred during the incident; that is, the bloodstain patterns help us understand not only the nature of the action that created them, but also where in the scene these actions occurred, any direction or motion associated with these actions, and in what order the actions occurred. The ultimate conclusions offered by the analyst are intended to put this information into a context for the incident in question, associating them when possible to specific acts or actions (e.g., associating an impact pattern to a gunshot) by involved parties.

Historical Perspective of Bloodstain Pattern Evidence

In seeking an understanding of bloodstain pattern analysis, it is important to look back at its evolution. In his book, *Blood Evidence*, Craig Lewis wrote: "The science of bloodstain pattern analysis, a field in which the only textbook in existence was written by MacDonell, was little known."[3] This viewpoint, although inaccurate, is not uncommon. Out of ignorance, authors, judges, and investigators continue to proclaim the discipline as something "new."

To those who spend time at scenes of violent crime, it seems unimaginable to ignore the presence of blood, or not ask some simple questions as to its relationship to the crime. As we will discover, bloodstain pattern analysis has a nearly 150-year history that predates many modern forensic disciplines. This history is a consistent history. Although study and research have increased our overall understanding of cause and effect in bloodstain pattern analysis, the basic ideas that early pioneers claimed they could apply, we can still accomplish. Therefore, it is helpful to understand the genesis of bloodstain pattern analysis.

The mere presence of blood, excluding any formal analysis, has long been held as evidence of foul play. For example, in the development of early Germanic law, tribal code (private, as compared to state) was often created. One of the surviving documents of

this nature is the *Sachsenspeigel*. Compiled as a record of Saxon custom, a knight named Ritter Repkow wrote the document during the period of 1220–1235. Common Law II, 63, Article 1–3 dealt in part with the raising of the "hue and cry" and the necessity of proving one's innocence for acting against a criminal caught in the act. He who had acted was required to prove an incontestability of the criminal's deed.[4] Examples of this proof, although not quite beyond a reasonable doubt, included "a criminal caught red handed."[5] The *Sachsenspeigel*, with its detailed illustrations, refers to the criminal having been caught with blood on his hand.

The work of William Shakespeare, although not the typical reference material of the criminalist, is filled with references to blood and the prejudicial nature by which its discovery is viewed. Shakespeare's various works, written between 1582 and 1616, like all those of authors, reflect the perceptions of his time. For example, in Act II, Scene II of Macbeth, after stabbing King Duncan, Macbeth says:

> What hands are here! Ha! they pluck out mine eyes. Will all great Neptune's ocean wash this blood Clean from my hand?

The *Sachsenspeigel* and Shakespeare's plays may not be of significant concern to the modern-day bloodstain pattern analyst, but they do reflect the consideration of bloodstains as a basic issue, preceding the formal development of forensic science. They also reflect the prejudicial manner in which bloodstains are often viewed. An interesting artistic example of the prejudicial nature of bloodstains hangs in the Central Art Archives of Finland. The work is entitled *Fratricide*, by Akseli Gallen-Kallela (*circa* 1897). It shows a young man with a bloodied sword and clothing as his mother points to numerous stains on his clothing (see Figure 1.1).

Another author whose writings reflect man's inquisitive nature with blood evidence is Sir Arthur Conan Doyle. In 1887, Doyle wrote *A Study in Scarlet*, introducing the world to his brilliant character Sherlock Holmes. In this story, the master detective concerns himself not only with discovering a reliable reagent test for blood, but also in the examination of "gouts and splashes of blood, which lay all around."[6] Again, we see artistic indications that those concerned with the early investigation of crime considered the relationship of bloodstains to such crime.

Early Scientific References

Having considered literary references, it seems appropriate to turn our attention to the scientific evaluation of bloodstain patterns. We intend to discuss some of the more critical and insightful research conducted over the last century; however, there are many references that may not be mentioned or discussed in detail. The analyst should recognize this and consider seeking these historical references for greater enlightenment.

Europe was the primary location in which bloodstain pattern analysis found its initial footing. The primary periodical through which many of the continental authors expressed themselves was the *Viertaljahresschrift fur gerichtliche Medizin* (*Quarter-Year Writings for Forensic Medicine*), which was published in Germany. Although much of the concern between the period of 1850 and 1940 dealt with the identification of blood, scattered throughout these discussions are references to patterns observed at scenes.

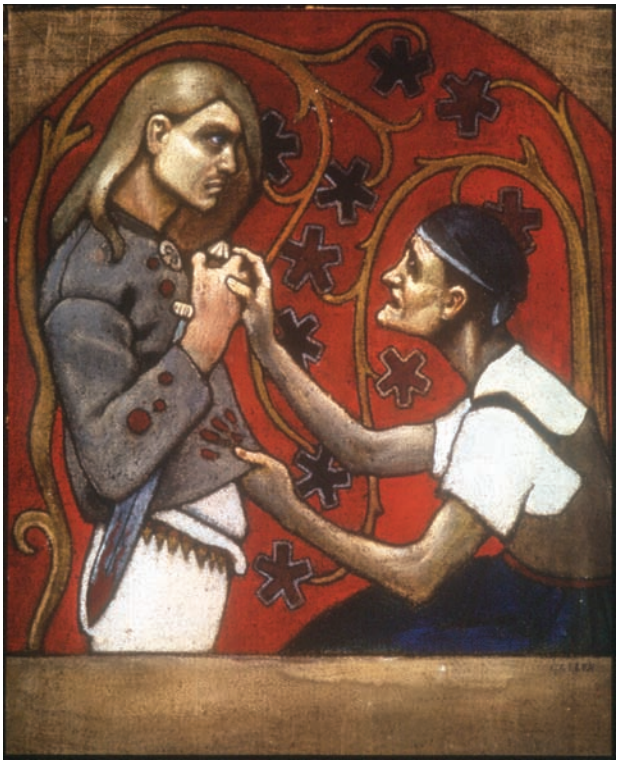

Figure 1.1 *Fratricide* by Akseli Gellen-Kallela (1897), a painting owned by the Anteneum, the Antell Collection, and the Central Art Archives of Finland, photographed by Hannu Aaltonen. Beyond the issue of his bloody sword, the pattern transfer and blood spots on the young man's garments speak his guilt to his mother. (Photo courtesy of the National Art Archives, Helsinki, Finland.)

Before proceeding, it is important to note that in German the term "*blutspritzen*" was widely used by various authors. This term is translated most often as "blood sprinkles."[7] There is, however, no absolute translation and the terms sprinkle, spatter, splash, or spurt are all acceptable usage.[8] It becomes difficult, then, to always understand the specific context intended by any author. Caution is in order when considering the translations offered here.

In 1856, J.B. Lassaigne wrote "Neue Untersuchungen zur Erkennung von Blutflecken auf Eisen und Stahl" ("New Examination to Differentiate Bloodspots from Iron and Steel"). In the latter section of his paper, Lassaigne discusses marks that appeared similar to bloodstains, but were caused by insects.[9]

Although, Lassaigne made it clear he believed "crushing" of dead flies created such stains, he implied having found such stains at scenes and associated their presence with the presence of flies. Based on the description, these stains seem similar to what we might refer to as "fly specks." Unfortunately, the translation and overall description by Lassaigne cannot satisfy the issue. Had Lassaigne found "fly specks"? Was he then establishing a causal connection without considering the regurgitation of blood by flies at bloodstained scenes? Whatever the case, Lassaigne's observations establish his attention to detail and concern for differentiating such stains from other types of bloodstains.

In 1863, John Beck and Theodric Beck wrote "Elements of Medical Jurisprudence." The article, as reviewed by Herbert MacDonell, discussed various cases in which bloodstain

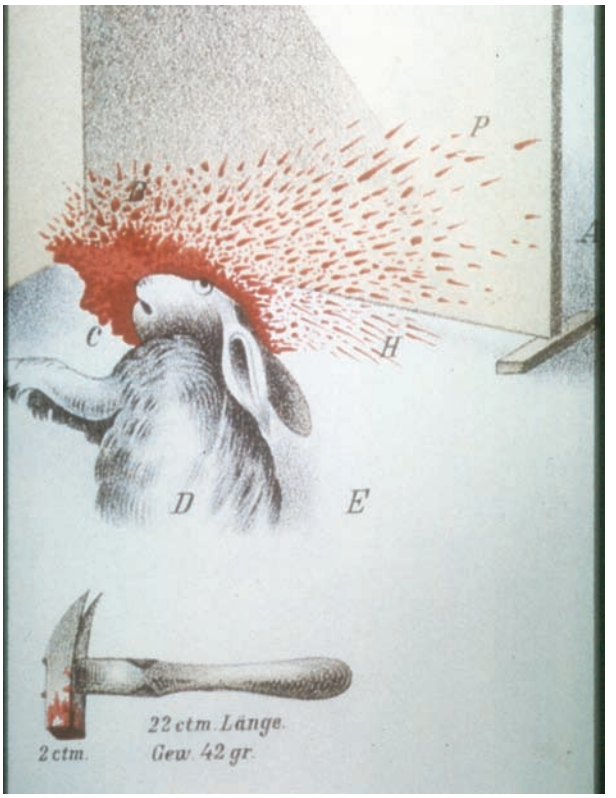

Figure 1.2 In addition to his written description, Piotroswki created detailed drawings of his various experiments and their results. (Photograph courtesy of Herbert MacDonell, Laboratory of Forensic Science, Corning, NY.)

pattern analysis was utilized. Specific references were made to the "situation" of wounds, and as MacDonell noted, the authors also used the term "blood sprinkles." The latter term tends to indicate a German influence, although the article originated in Philadelphia.[10]

In 1880, Dr. Henry Faulds published "On Skin-Furrows of the Hand," describing bloody fingerprints and their likely usage to identify the criminal.[11]

In 1882, Professor Charles M. Tidy of London published "Legal Medicine," in which he stated:

> Few things hold so important a place as, or involve investigations of a greater nicety, than determining the precise nature of various [blood] spots or stains found on fabrics, instruments…[12]

Perhaps one of the most impressive treatises written on the subject of bloodstain pattern analysis is "Ueber Entstehung, Form, Richtung und Ausbreitung der Blutspuren nach Hiebwunden des Kopfes," ("Concerning Origin, Shape, Direction and Distribution of Bloodstains Following Blow Injuries to the Head") written by Eduard Piotrowski in 1895 at the University of Vienna.

Dr. Piotrowski's application of scientific method to his observations and evaluations of bloodstains is unequaled in the known writings of the time. He reconstructed his scenes to model those in question, and controlled and adjusted various variables to determine their specific effect, his experiments using live rabbits (see Figure 1.2). Although the

use of live animal models would not sit well with many modern groups, Dr. Piotrowski recognized the dynamic nature of what he was studying, and felt the use of live subjects assisted his understanding.

Dr. Piotrowski considered this dynamic nature and used it as one of his variables. Calling the concept a "*complicirtem morde*," he used multiple methods of attack against his study subjects (rabbits); thereby ensuring himself that he was considering all possibilities and their effects.[13]

In considering this *complicirtem morde*, Dr. Piotrowski properly recognized bodily reactions of his subjects when struck. In the following example, he observed small stains "similar to dots" that radiated out from the rabbit's head, and concluded:

> As far as their position is concerned, they spread out in a radiating pattern. The center of this outward radiating droplet [pattern] was the nostrils and mouth from which the accumulated blood was forced out … [expectorate blood].[14]

Evident to Dr. Piotrowski was the correlation between the location of the stain's tail and the direction the droplet was traveling at impact. He also recognized the causative factors of cast-off stains. He included in his evaluation of the first the effect of a parabolic arc on the resulting stain. In the latter, he isolated not only the fact that blood flung from a weapon would create a specific stain, but also correlated this with stain directionality, giving him an ability to define the direction in which the weapon was being moved.[15] In this work's concluding statement, Dr. Piotrowski commented:

> The formation, shape, and distribution of bloodstains follow specific rules and that these, allowing for many modifications considering the nature of the case, are not to be underestimated and are of great value in the judgment.[16]

In 1901 Jurgen Thorwald, writing about the efforts of Professor A. Florence stated:

> [Florence] had worked out a whole system for classifying bloodstains caused by dripping, splashing, spurting, or grazing contact. Round stains, or roundish jagged stains, for example, indicate that blood fell vertically; oblong stains result from impact at various angles.[17]

Thorwald based his discussion on Florence's article "Les Taches de Sang au Laboratoire De Medicine Legale De Lyon." This article originally appeared in the *Archives De Anthropolgie Criminelle* in 1901.

In 1902, Dr. John Glaister discussed the role of bloodstains in his book *Medical Jurisprudence Toxicology and Public Health*. As with other authors of his time, Glaister's primary concern was the issue of whether various stains were or were not human blood, but he also commented on patterns of blood and, in particular, the basic pattern types:

> As has already been pointed out, in every case in which a dead body with wounds upon it is examined *in situ*, examinations should be carefully made for the presence of blood-stains and their incidence upon the body and in its vicinity. The examiner must expect to meet every possible variety of stains, both in respect to character, incidence and magnitude: as (a) sprays, spurts, or jets; (b) smears of various forms; or (c) pools of blood."[18]

Dr. Glaister did not further refine his ideas of what these different patterns looked like, but it is clear investigators at the time were considering not only the presence of blood, but also the nature of the bloodstains.

In 1904, Hans Gross wrote *Handbook fur Untersuchnungsrichter Als System Der Kriminalistik*. In it he provided a detailed discussion of not only the evaluation of bloodstains, but also their collection and documentation.[19] Gross felt bloodstains were of critical importance in the investigation, and he devoted some 30 pages of the book to his considerations of blood and bloodstain patterns in the investigative process (see Figure 1.3). This book was considered *the* reference of its time, and in 1924 with Gross' permission, it was translated into English and republished by J. Collyer Adam as *Criminal Investigation*.

Figure 1.3 One of many drawings from Gross' translated text. This drawing depicts variations in the shape of a stain as a function of how it falls to the ground (the impact angle), and the correlation of satellite stains and scallops to the directionality of the stain.

In 1912, Russian Professor R.A. Reiss discussed the use of bloodstain patterns in an article entitled "Scientific Techniques of Criminal Investigation." His primary considerations were shape, but also included a discussion of arterial patterns and concern over the difference between stains on an absorbent target compared to those on a non-absorbent target.[20]

In 1914, Haberda wrote "Eine besondere Form von Blutspritzen" ("A Special Form of Bloodstain"), discussing a specific pattern observed in airway injuries. He described such stains as droplets of various shapes that contained small air bubbles mixed with the blood. Beyond his consideration for this particular stain, Haberda offers many insightful lessons which are still applicable. Consider the following:

> The discovery of quantity, spread, form, and arrangement of bloodstains at a blood spattered crime scene can be of high importance. Evaluation requires many years of experience, usually learned little by little through practice, but never from books. Never the less, experts are often not careful enough when it comes to the necessary evaluation.
>
> Forced by precise questions of police, jurisdictional or governmental authorities, the experts sometimes answer too exclusively and draw the wrong conclusions about the bloodstains on a corpse or in the surrounding crime scene.[21]

We would agree wholeheartedly that oftentimes analysts make conclusions that are far too exclusive.

Haberda also made reference to bloody fingerprints, clothing pattern impressions, and his particular stain — the foamy bloodstain. In describing the shape of stains that might be encountered, Haberda said:

> Even though the distance of the fall, or the angle with which the blood hits the ground influences the shape of bloodstains, which are for example more or less round, bear paw like, club or bottle like…[22]

How similar to modern descriptions are Haberda's? *Round* and *bear paw* are still adjectives used to describe stains, whereas *elliptical* replaced terms like *club* or *bottle-like*. There can be no doubt Haberda was observing and classifying the very things we still look for today.

Ernest Ziemke is another author of interest. His work is found in *Gerichtsarztliche und polizieartzliche Technik*, a book written by Theodor Lochte in 1914. Chapter 7, entitled "Die Untersuchnung von Blutspuren" ("The Examination of Blood Tracks"), was written by Dr. Ziemke. The work includes 14 pages of text with numerous pictures; it details various stains and the information represented by those stains. Ziemke dealt with a wide range of issues affecting bloodstain pattern analysis.

In the chapter preamble, Dr. Ziemke states:

> Blood tracks [blood effects or evidence] are the most important tracks that stay behind after a crime is committed. Very often they alone have been of significant enough importance for the conviction of the suspect, and have been the focal point in a trial with only circumstantial evidence… Their evaluation should be efficient, because during an investigation it may be hard to foresee what might be of importance later during a court trial.[23]

In discussing the search for blood, both for serological and bloodstain pattern evidence, Dr. Ziemke offers that:

> The suspect, his clothes, all items he carries, or which are in his pockets should be carefully examined for bloodstains.[24]

This is sound advice that some of the best bloodstain pattern analysts in the country continually stress and teach today. Far too often, such minute traces are simply overlooked by investigators.

In discussing pattern analysis and the conclusion drawn, Dr. Ziemke comments:

> Very important conclusions can be drawn from the arrangement, location, size, and form of bloodstains … Based on our own experience and experiments we want to point out that it is necessary to be cautious and not draw conclusions from a single or very few blood tracks. This happens quite often… Only when a large number of bloodstains are examined and compared, is it possible to exclude errors [in logic].[25]

Dr. Ziemke provided detailed descriptions of various types of bloodstains. His terminology followed that of Piotrowski, but he added terms such as "thorn apple shaped" to refer to the bear claw stain. He acknowledged that secondary droplets (satellite stains/wave cast-off stains) in these instances would assist in understanding the direction of motion of the blood droplet. He included figure examples of cast-off blood and drip patterns in which he described how to define directionality. Figure 1.4 is an example of one of these illustrations. In closing his discussion of bloodstain patterns, he said:

> When the examination of bloodstains is done efficiently and carefully, and if all possibilities are exhausted, shape, location, and the site of the bloodstain can give important details about the circumstances of the deed, eventually even be of importance for the conviction of the suspect.[26]

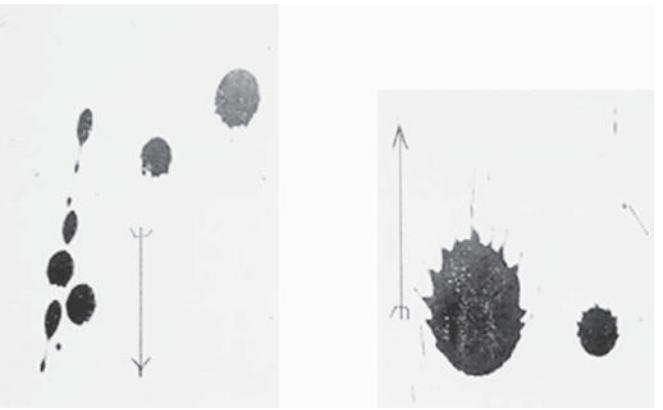

Figure 1.4 Illustrations from Dr. Ziemke's chapter on bloodstain pattern analysis. The two figures (Ziemke's Figures 42 and 43) demonstrate a drip effect from walking and running. Ziemke added the arrows to show directionality evident in the stains.

Dr. W.F. Hesselink considered various issues related to bloodstain analysis in his article "Blutspuren in der Kriminalistchen Praxis" ("Bloodtracks in Criminalist Practice") written in 1931. For example, Hesselink considered the subsequent condition of the dried stains on clothing as a manner of differentiating whether such clothing had been worn or in use since the deposit of the stains. He also considered a method of dissolving the bloodstain to determine its relative age when compared to some other stain. Hesselink eventually concluded this technique was inaccurate, indicating that the manner in which each droplet dried and coagulated would affect the results.

He also considered whether a suspect would or would not be stained in a violent murder, making the following observations:

> The answer depends upon two main circumstances: one, if many bloodstains are found at the scene, and two, what instrument was used. Regarding this I did several experiments. When using the hammer, the liquid squirts in all four directions, and will also cover the suspect. If a stick is used, the blood squirts left and right, and the suspect might not show any blood marks. When a forward bent file is used, the blood squirts only to the front. The foreground [of an illustration] shows many spatter while only a few went towards the subject. While the suspect of a bloody murder, performed with a hammer, usually will be bloodstained, the suspect, in case of death caused by hitting with a bent file might have few or no bloodstains on the clothes.[27]

Hesselink then described the use of a pattern transfer he discovered, stating:

> In one murder, I found a blood spot on the bedroom floor. First, it did not look too informative, but when I examined it later with a very strong light, I found remarkable prints of about 14 shoe nails.[28]

Hesselink sought not only to define the nature of the stains found, but also to define the manner of the event creating the stains. He then correlated the information with other forensic evidence, resulting in a partial reconstruction of his scene and the crime. His recognition of the importance of bloodstain pattern analysis for scene reconstruction is reflected in his closing statement:

> Therefore, when examining blood, the blood investigation [to identify a substance as blood] itself is not as important as the clarification of surrounding circumstances.[29]

In 1931, Henry T.F. Rhodes, a criminologist in England, member of the International Academy of Criminology, and an admirer of the great criminologist Edmund Locard, published *Some Persons Unknown*. The book was a compilation of case studies with a history of the scientific development of criminology. Although Rhodes did not discuss the use of bloodstain patterns in and of itself, he discussed in depth the development of the identification of blood in forensic investigation. He commented on the ever-increasing discrimination required by the court in terms of making identification of blood. Rhodes stated this manifested itself in the change of accepted testimony from "it looks like blood," to "yes it is blood," to "yes it is blood and it is human." At the time of publication, the four categories of blood, which ultimately became known as the ABH/ABO grouping system, had just been discovered. Rhodes recognized this advancement as a significant investigative tool with which to primarily exclude individuals as suspects.[30]

Rhodes followed his first book with a second entitled *Clues and Crime*. Published in 1933, the theme of the book was consideration of how science assisted in the detection of crime. Although Rhodes did not personally comment on bloodstain patterns, he gave specific mention to the efforts of Hans Gross in the area of bloodstain pattern analysis.[31]

In their writings it is obvious that Hesselink and Rhodes clearly viewed blood in different perspectives. Rhodes understood what Gross was pursuing in the area of bloodstain patterns, but still felt the scientific individualization through the blood grouping systems of the time was of greater significance. Hesselink, on the other hand, felt that individualization and identification were secondary, and that the patterns themselves were of greater significance. Today we recognize that both were correct. The individualization of bloodstains without consideration of the pattern itself or vice versa is tantamount to reading a book but skipping chapters.

In 1939 at the XXII Congress of Forensic Medicine, Dr. Victor Balthazard, R. Piedelievre, Henri Desolille, and L. Derobert presented one of the most insightful papers relating to bloodstain pattern analysis. Entitled "Etude Des Goutes De Sang Projecte," the proposed purpose of the research was to pinpoint characteristic elements of a bloodstain which might "give decisive hints" as to its origin.[32]

Balthazard et al. felt it necessary not only to examine the resulting spatter and stains, but also to understand the manner in which blood exits wounds, the trajectories of such blood, and the manner in which the blood droplet changed to become the resulting stain. As with Piotrowski, Balthazard recognized the importance of the dynamics involved in bloodshed, and realized bloodshed could not always be mimicked under laboratory conditions. To provide more realistic data, Balthazard utilized rabbits to produce actual bleeding injuries.[33]

Balthazard's consideration of the length-to-width ratio of a stain as a function of impact angle is one of the most important contributions of this work. Analysts repeat his experiment in nearly every 40-hour bloodstain pattern analysis course taught today. Professor Balthazard offered a caution in considering impact angle estimations, however, stating:

> In practical application, it [impact angle evaluations] should not be looked after for an illusionary accuracy. Nevertheless, this curve permits an estimate of the impact angle with an acceptable accuracy, sufficient for practical purposes.[34]

Another important consideration was determining the point of origin. Balthazard furthered the cause and process for making such estimations. His group's efforts established the basis for current "stringing" techniques. Yet, in considering the issue of the unknown parabola of the droplet, Balthazard stated:

> Practically these methods can only be applied in a limited manner. [For instance] sometimes it is necessary to find out whether a victim, at the moment he was injured, stood on his feet or was lying.[35]

Finally, Balthazard's group considered the nature of the target on which a droplet fell. They found that many deformations would be possible, given various target characteristics. In summary, Balthazard stated:

> These modifications [deformations caused by the target] are sometimes obvious, but we must constantly remember that on an apparently homogeneous target, uneven areas can occur which may cause slight disfigurations.[36]

It is likely that world events in Europe prevented further effort in developing the research of Balthazard and his fellow researchers. Nevertheless, their efforts were not completely lost or without some impact. In 1941, John Gohringer, a U.S. citizen studying for his medical degree at the Institute of Forensic Medicine, University of Heidelberg, wrote as his inaugural dissertation "Kann Aus Dem Bild Auf Verscheidenen Unterlagagen Die Fallohe Und Richtung Des Gefallenen Tropfens Ermittelt Wreden?" ("Is It Possible To Establish The Falling Height and Directionality of a Dropped Down Drop Of Blood from the Appearance of the Stain on Various Targets?"). Much of Dr. Gohringer's inspiration developed out of Balthazard's research. As an interesting historical note, Dr. Gohringer completed his studies in December of 1941 and was subsequently held as an internee by the German government for seven months before he was released to Vienna.[37] He later returned to the U.S., where he left forensics and began practicing medicine. In 1992, Dr. Gohringer had occasion to speak before the International Association of Bloodstain Pattern Analysts, (IABPA) training conference in Colorado Springs, Colorado, sharing some of his thoughts on the history of bloodstain pattern analysis.

Dr. Paul Leland Kirk, of Berkeley, California, also added immeasurably to the knowledge of bloodstain pattern analysis. Dr. Kirk, a professor of criminalistics and biochemistry, was active in assisting law enforcement organizations in the U.S. between 1935 and 1967. Dr. Kirk's book, *Crime Investigation*, published in 1953, included a chapter entitled "Blood: Physical Investigation." In that chapter, Kirk discussed the application of bloodstain pattern analysis to criminal investigations.

Another source for Kirk's beliefs on the subject is evident in his affidavit filed in the Court of Common Pleas, Criminal Branch, in the case of *State of Ohio v. Samuel H. Sheppard*. This document provides immense insight on his approach to bloodstain analysis.

In the Sheppard case, Dr. Kirk considered the drying times of blood and the evaluation of blood trails as evidence. He specifically sought to evaluate plausible causes for such trails. Further, he identified a void in the bedroom of Mrs. Sheppard that others missed, which established the most likely position of the attacker. He then correlated the cast-off patterns found in the room to the position of this void. Dr. Kirk clearly utilized a whole-scene approach.[38]

In 1955, Svensson, Wendel, Sodermann, and Stenlund published *Rikospaikka-Tutkimus* (*Techniques of Criminal Investigation*) in Helsinki, Finland. The text included 12 pages depicting various aspects of bloodstain pattern analysis and describing its role in the criminal investigation. Although the primary purpose of the text was to explain what kind of evidence to look for and how to collect it, they also described basic types of patterns, discussed directionality, and understood that bloodstain pattern analysis was an integral part of violent crime investigation. In 1965, American Elsevier Publishing reprinted the book in English.

In 1960, Dr. Jozef Radzicki of Warsaw, Poland, published "Slady Krwi w Praktyce Sledczej" ("Bloodstain Prints in the Practice of Technology"). Although a full translation is not yet available, portions were translated for inclusion in the IABPA library. In this work, Dr. Radzicki established three basic groups of bloodstains, based on their mechanisms of creation. They are:

1. Bloodstains resulting directly from extravasations — drops, gushes, and pools of blood
2. Bloodstains resulting from the application of various instruments — spatter, cast-offs, and patterns resulting from direct contact
3. Bloodstains resulting from the wiping or removal of blood[39]

As with previous authors, Radziki cautioned that a critical consideration was the characteristics of the target surface, as bloodstains created under similar circumstances but falling to different targets might well result in dissimilar stains. Several other interesting points made by Dr. Radziki included his consideration that "how" an instrument was employed would clearly affect the nature and distribution of the resulting spatter. Dr. Radziki also discussed arterial bloodstain patterns in depth.[40]

Modern Works in Bloodstain Pattern Analysis

Having dealt with a "historical" view of bloodstain pattern analysis, we arrive at a more recent history. Following Dr. Kirk's efforts through the 1960s was what might be considered the modern renaissance of the discipline. The number of authors writing on this subject increased dramatically, professional associations related to the field were established, and the discipline as a whole took on a far more accepted status in court.

Many proclaim Herbert MacDonell as the father of modern bloodstain pattern analysis. Whether this is accurate depends upon your individual perspective. What cannot be denied is that Herbert MacDonell brought about a distinct reawakening of this discipline.

In 1970, after conducting extensive research, MacDonell and Lorraine Bialousz co-authored *Flight Characteristics and Stain Patterns of Human Blood*. As the two were working under a Law Enforcement Assistance Administration (LEAA) grant, the LEAA published the report. The LEAA document remained available for nearly 12 years before going out of print. In 1982, the revised paper was released as *Bloodstain Pattern Interpretation*. MacDonell subsequently completed a third work on the subject in 1993, entitled *Bloodstain Patterns*.

In 1983, Dr. Henry Lee, Peter Deforest, and Dr. R.E. Gaensslen wrote *Forensic Science: An Introduction to Criminalistics*. Included in this work is a 12-page section dedicated to explaining bloodstain patterns.

In 1983, the IABPA was formed. The association's stated purpose is to promote the general knowledge, techniques, and understanding of bloodstain pattern evidence.

In 1986, the *Journal of Forensic Science* published two papers by Peter Pizzola, Steven Roth, and Peter Deforest, entitled "Blood Droplet Dynamics I and II." The group sought to examine the dynamics of liquid droplets in flight and photographed droplet impacts, providing a more accurate understanding of the action that is often called "wave cast-off." In "Blood Droplet Dynamics II," Pizzola et al. clearly demonstrated that motion in the target could mimic characteristics of an impact at a greater angle than that which occurred. Their findings are extremely important in our efforts to understand dynamic scenes of crime.[41]

In 1989, William Eckert and Stuart James published *Interpretation of Bloodstain Evidence at Crime Scenes*. Although the book received a very critical review in the *Journal of Forensic Science*, it was the first attempt in almost seven years to tackle bloodstain pattern analysis as a single reference text.

The following year, the International Association of Identification accepted bloodstain pattern analysis as a discipline, removing it as a subcategory of crime scene analysis. That same year, we wrote *Bloodstain Pattern Analysis: Theory and Practice: A Laboratory Manual*.

In 1998, James and Eckert published their second edition of *Interpretation of Bloodstain Evidence at Crime Scenes* with CRC Press, significantly adding to the book's value. Prior omissions were corrected and the text remains a valuable reference.

James followed this work with *Scientific and Legal Applications of Bloodstain Patterns Interpretation*. James put together an impressive group of contributors, including Alfred Carter, William Fischer, Carol Henderson, Paul Erwin Kish, Maria Saccoccio, and T. Paulette Sutton. The text was directed toward trial counsel in an effort to help lawyers better understand how to apply bloodstain pattern analysis in criminal trials.

In 2001, Anita Wonder published her book, *Bloodstain Dynamics*. Although from an overall viewpoint this work is a significant resource, Wonder included issues that were, to say the least, controversial. This included the claim that she could differentiate the nature of spatter based on a single stain from any spatter pattern. Despite some of these more controversial issues, the book remains an excellent resource for the discipline.[42]

In 2002, the Federal Bureau of Investigation formed the Scientific Working Group for Bloodstain Pattern Analysis (SWGSTAIN). Calling on expertise from police, laboratory, and independent consultants worldwide, the purpose and focus of this group was to explore and define functional guidelines for the discipline.

In 2005, Stuart James, along with co-authors Paulette Sutton and Paul Kish, published *Principles of Bloodstain Pattern Analysis Theory and Practice* with CRC Press. This work was a far more comprehensive document than his previous text, *Bloodstain Evidence at Crime Scenes*.

Summary

Whatever we might say of bloodstain pattern analysis, it has a rich history; one that indicates the consideration of bloodstains in solving crime predates even modern forensics. As to the issue of being a "new" discipline, the examination and consideration of bloodstain patterns and their historical acceptance in forensics is well documented. Bloodstain pattern analysis has a nearly 150-year documented history; and as important as the length of that history is, just as important is the fact that it is a consistent history. Long recognized for its

ability to support the evaluation of scenes of crime, bloodstain pattern analysis serves the investigator by illuminating "what happened." It cannot tell us in all cases "who," but as Piotrowski and Hesselink discussed, the ability to define the "situation" or "circumstances" of the crime is often just as important.

Working with an understanding of all areas of forensics and with experience in evaluating crime scenes, the investigator can often use bloodstain pattern analysis to reconstruct the events surrounding a given incident. More and more, this process of crime scene reconstruction is being tested in our judicial system, but it is only through the application of quality objective analyses that the discipline can hope to serve its intended function. Our purpose as analysts must always be to guard against subjective analysis.

As we wrote in 1990, each day blood from scenes of a crime cries out to investigators. The use of proper bloodstain pattern analysis simply enhances the criminalist's ability to be an active listener to this very vocal witness.

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Bloodstain Pattern Terminology

2

Given that various organizations and individuals have helped define the history of bloodstain pattern analysis, as well as the existence of a number of different bloodstain classification systems, the reader should not be surprised that no single set of terms is available for bloodstain pattern analysis. Unfortunately, every analyst has a way of adding and customizing terms. In this chapter, we offer our own perspective of terminology. This terminology should not be construed as all-inclusive or absolute, but we will attempt to encompass varying ideas on the subject.

Referring to the Discipline

Perhaps the first term to deal with is the name of the discipline itself. In discussing bloodstain pattern analysis, one is likely to find both well-trained and not so well-trained analysts using terms such as:

- Bloodstain pattern interpretation
- Blood spatter analysis
- Bloodstain spatter analysis
- Blood splatter analysis/interpretation
- Bloodstain pattern analysis

The term preferred by the authors is bloodstain pattern analysis. This wording is preferable for numerous reasons. First and foremost, *analysis* implies a structured approach of evaluating that which is to be examined. Analysis is an examination in detail in order to determine the nature of that examined or to determine interrelationships present.[1] *Interpretation,* on the other hand, alludes to a more subjective viewing. An example of this difference might be in the area of questioned documents. At any side-street carnival, you may have your handwriting interpreted to reveal your "true personality." At a crime laboratory, however, the examiner of the document analyzes the physical nature of the writing in an attempt to identify the originator. So, too, the bloodstain pattern analyst must examine the physical nature of stains. It is not that acceptable "interpretation" of a crime scene is bad; it is simply that we wish to exclude, whenever possible, references to actions that can be construed as subjective and therefore unscientific. Can bloodstain pattern analysis be considered an interpretation? In a technical sense yes, but it is far more accurate to define it as a deductive and inductive analysis following the scientific method.

There is a clear reason to use *pattern* vs. *spatter* or *splatter* because technically analysts evaluate all types of bloodstain patterns. Spatter is a specific type of bloodstain; properly, a bloodstain spatter analyst would be one who analyzes only spatter. Bloodstains found at scenes of crimes run the gamut for their source of origin. Stains such as swipes, pattern transfers, or blood pooling are not spatter. Thus, a bloodstain pattern analyst examines all

patterns of blood in detail to determine their nature and interrelationships, no matter what their source.

Now that we have introduced the terms spatter and splatter, it seems appropriate to tackle what are likely the most misused terms in bloodstain pattern analysis. When discussing bloodstain pattern analysis with someone newly introduced to the subject, the term "splatter" is likely to be heard.

There are two reasons for not using this term. First, the term lacks an aesthetic value: "splatter" in a sentence goes over about as well as castor oil. If one can be prejudiced to a word, then we are. To say the least, splatter is obtrusive and rough. It is certainly not one of the more fluid words found in the English language.

A second, less subjective concern is that splatter has usage singularly as a verb, whereas spatter has usage as both a noun and a verb. When discussing bloodstain pattern analysis, it can be said that most references to a splatter or spatter are to some "thing" being evaluated. Thus, the noun spatter is the only proper usage in those instances. In a few isolated situations, the speaker or writer may well be discussing the act of causing spatter, during which splatter (or more likely, splattered) could be properly used.

General Terms Relating to Bloodstain Pattern Analysis

The terms, definitions, and discussion that follow are intended to assist an analyst in understanding and conversing in the discipline of bloodstain pattern analysis. Although perhaps not absolutely complete, they will certainly serve as a basic vocabulary for anyone interested in the discipline. Note that although the primary pattern types are mentioned in this chapter, the full gamut of bloodstain pattern classifications is described in detail in Chapter 3. Terms of interest to the analyst include the following:

Angle of Impact

The acute angle as viewed from the side, created by the intercept of the target by the droplet's vector (see Figure 2.1).

When blood drops strike a target, they do so at some angle. The angle of impact is relative to the surface of the target itself. For instance, drops or spatter traveling straight down and impacting the floor have an impact angle of 90°. Drops traveling horizontal to the floor

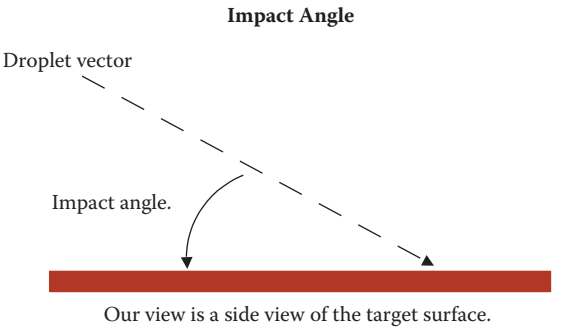

Figure 2.1 Impact angle: the acute angle (less than 90°) at which a droplet strikes a given target.

and impacting a wall may also have an impact angle of 90°. The possible measurements of the impact angle can be expressed in a range from the most acute angle, 1°, to a maximum of 90°. Much of the application of mathematics to bloodstain pattern analysis deals with defining these impact angles and determining the area of origin for the stains evaluated.

(Arterial) Spurt/Gush

The escape of blood under pressure, typically from a breach in an artery or heart, showing pressure, pressure fluctuations, or both (see Figure 2.2 and Figure 2.3).

Spurts and gushes are two distinct pattern types and are described in depth in Chapter 3. They most often occur as a result of a breached artery; as such, when one refers to a spurt or gush it is invariably described as "arterial." Blood present in the arteries flows under greater pressure than blood present in the veins. Although, depending upon which aspects of the two systems we compare, this difference may not be great.[2] If an artery or the heart itself is breached through some wounding mechanism while the heart is functional, the resulting pattern will likely exhibit both the increase and decrease of the arterial pressure as it flows from the wound and the force of projection behind the flow. As Brodbeck discussed, in some instances veins may produce streaming ejections as well, giving foundation to the concern of referring to the pattern as a spurt or gush only.[3]

Figure 2.2 An arterial spurt resulting from a cut carotid artery. In this instance, the blood was projected more directly into the target, resulting in the "trail" appearance. Still evident in the stain are spines (indicating the force of projection) and several small indications of pressure fluctuations. (Photograph courtesy of Jeff Svoboda, Fort Collins Police Department, Fort Collins, CO.)

Figure 2.3 An arterial gush resulting from a gunshot wound to the femoral artery.

Gushes are large-volume patterns in which the pressure variations are less distinct simply due to the volume of blood gushing out of the wound. Spurts usually represent a smaller volume of blood. (Volume in this instance refers to the amount of blood escaping the wound at that particular moment, not the total volume lost.)

The most typical spurt pattern reflects this rise and fall of pressure in up-and-down trails of blood on surrounding surfaces. The pattern may have a zigzag appearance with distinct termination points, or a more wave-like appearance.

Atomized Blood/Misting

Bloodstain patterns characterized by a mist-like appearance, which are generally associated with an explosive force such as a gunshot (see Figure 2.4).

When sufficient force or energy is applied to a blood source, the blood may be reduced to a fine spray, resulting in atomized bloodstains. Such an effect is also referred to as a misting effect or misting stains. These stains are most typical of situations in which there is an explosive force such as a gunshot.

The resulting pattern consists of many small, generally circular, stains. The individual stains may be macroscopically indistinguishable within the overall pattern, producing an area that appears as a reddish hue, as if lightly spray-painted. The number of these individual stains may be in the teens, or it can exceed hundreds. The actual number found at a given scene is dependent upon several factors including but not limited to the nature and site of the injury, intermediate targets such as clothing, and the nature of the wounding projectile(s). Atomized stains follow the general principle that as the force applied to the blood source increases, a decrease will be observed in individual stain size. The overall diameter of such stains will measure a mere fraction of a millimeter.

Blood into Blood Patterns

A pattern created when drops are deposited into one another or into another liquid resulting in an accumulation of blood surrounded by randomly oriented secondary spatter (see Figure 2.5).

Figure 2.4 A misting stain associated with a gunshot. Just below the locking mechanism of the door is an area saturated with small sub-millimeter stains.

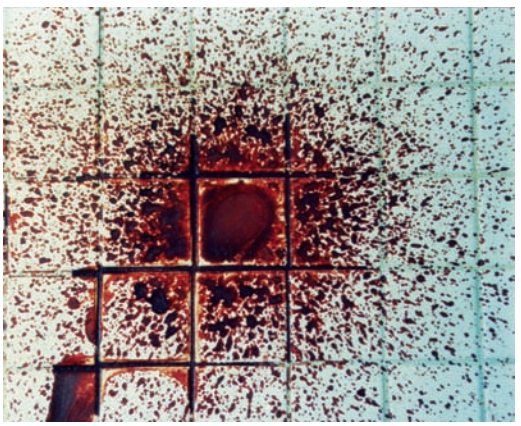

Figure 2.5 A blood into blood pattern. These patterns are produced by drips.

Blood into blood is a specific classification of pattern described in Chapter 3. It occurs when blood drips into blood or another accumulation of liquid. These patterns have characteristic traits whether found on vertical or horizontal surfaces.

On a horizontal surface, the drip pattern causes random, somewhat irregular stains all about the pooled or standing blood. If the satellite stains from a drip pattern intermix with impact spatter, it may be difficult to differentiate between the two.

When created in proximity to a vertical surface such as a wall, a voided area may be found in the pattern on the vertical surface. This pattern resembles a funnel or is V-shaped. Chapter 3 and Chapter 10 discuss drip patterns in greater detail.

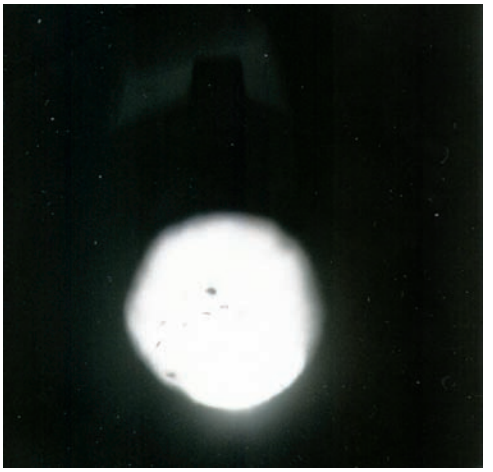

Figure 2.6 An example of blowback effect. Stains are evident in the barrel of this .357 revolver. The weapon was used in a suicide with hard contact to the head. The photograph was taken using a fiber optic light, which was inserted into the breech of the barrel. (Photograph courtesy of Don Blake and Bill May, Norman Police Department, Norman, OK.)

Blowback Effect

The process in which blood is deposited inside the barrel of a weapon after discharge (see Figure 2.6).

In instances of gunshot injuries involving close or near contact wounds, blood will often be found within the barrel of the weapon. This is a result of the blowback effect. Whether blowback is directly related to back spatter is still questionable. Some explanations have been based on claims that an over-pressure in the wound coupled with a near vacuum in the barrel cause contaminants (blood and tissue) to be sucked up the barrel as air rushes back in to fill this void. More probable is a correlation to temporary wound cavity and the creation of back spatter as the source of these stains. Whatever the specific cause, blood and tissue have been found as much as 10 in. up a barrel. This distance of penetration in the barrel may provide information relevant to the distance between the wound and the weapon when it was fired.[4]

Capillary Action

The force exhibited in the attraction of a liquid to surfaces with which it is in contact and its own surface tension. This attraction often results in stain characteristics for which no corresponding defect may exist.

When discussing capillary action in bloodstain analysis it is evident that the definition does not strictly follow the scientific definition of capillary attraction. The latter is the force resulting from surface tension and adhesion of liquids when in contact with solids. In bloodstain pattern analysis, this term is used to describe two observed actions that are related to capillary attraction.

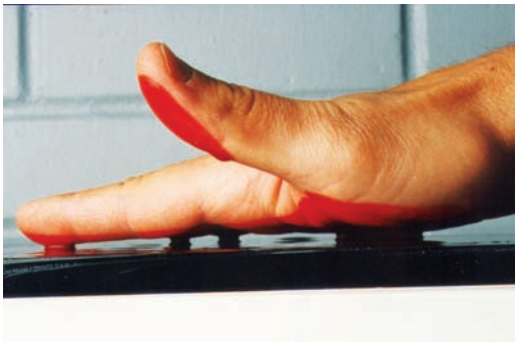

Figure 2.7 An example of capillary action. As the hand is withdrawn, the surface tension of the liquid in conjunction with its adhesive quality causes a bridging effect. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

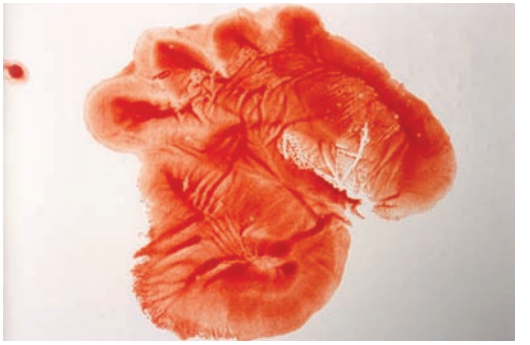

Figure 2.8 The result of Figure 2.7. Distinct linear features are present in the pattern because of the capillary action. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

The first is the action evident when two objects in contact are separated while blood is in-between. An example is a bloodied hand that is lifted off a floor or wall. The adhesive force of the blood with the surfaces of the solids acts to anchor the blood on both objects. At the same time, the surface tension of the liquid attempts to hold the blood together as a single entity. This anchoring, combined with the action of the surface tension, causes the liquid to be stretched across the expanding gap as the objects separate. Obviously, the surface tension of the liquid will eventually be overcome, but in the process the liquid is drawn together between the objects causing a line or demarcation which has no correlating trait on either of the objects creating the stain. As in the case of the hand, the stain may reflect linear characteristics for which no correlating defect exists. Figure 2.7 demonstrates this action, while Figure 2.8 shows the result.

A second usage encountered is to describe blood flow around objects. An example is a flow of blood from a wound that then comes in contact with the victim's arm. Obviously, the arm acts as a barrier, but the adhesive nature of the liquid to the arm may also give rise to what could appear as unnatural blood flow.

Cast-Off Patterns

Patterns created when blood is flung or projected from an object in motion or one that suddenly stops some motion (see Figure 2.9).

Cast-off patterns are a specific classification of pattern described in Chapter 3. Sometimes referred to as swing cast-off, they result when blood adheres to some object. When the object is put in motion, the blood is flung from the object at different points along its path. The nature of this object may be a weapon (e.g., a club or hammer) or perhaps the victim or subject (e.g., a hand or hair). Cast-off events create linear spatter patterns that reflect the general position of the item from which they were flung; in some instances, they may identify the minimum number of blows struck and will almost always provide information as to the direction or motion involved in their creation.

Figure 2.9 Two cast-off patterns. The two distinct linear patterns on the cabinet are cast-off, produced by a bloody object that was swung right to left.

The size of the spatter in a cast-off pattern will vary from object to object. Size of spatter is a function of surface area on the object, volume of the blood available, and velocity of the swing; for instance, the linear spatter produced by the tip of a knife blade is much smaller than that produced by a baseball bat.

Another form of cast-off pattern is the cessation cast-off, created when blood is flung from the object as it comes to an abrupt stop. Cessation cast-off is difficult to discern because unlike swing cast-off which ejects from the object over time and space (resulting in the linear/curvilinear characteristic), cessation cast-off is ejected from a point source. For this reason, cessation cast-off may look very similar to impact spatter.

Clot

A gelatinous mass formed by the collection of blood cells in fibrin; this mass will usually exhibit separation of the liquid and solid materials (see Figures 2.10).

A clot is considered to be any mass of congealed blood and other contaminants created through the natural clotting mechanisms of the body. Under normal conditions, blood within the vessels maintains its liquid state; however, when drawn from the body it thickens to form a gel. The clot consists of the cellular components of the blood. Clots can occur in any volume accumulation of blood; thus, we do not consider them a specific type of bloodstain pattern. Rather, a clot is a condition that may occur in another pattern. Serum separation is often observed late in the clotting process. At this stage, a straw-colored liquid is evident around the congealed mass. This serum is simply plasma without the blood solids.[5]

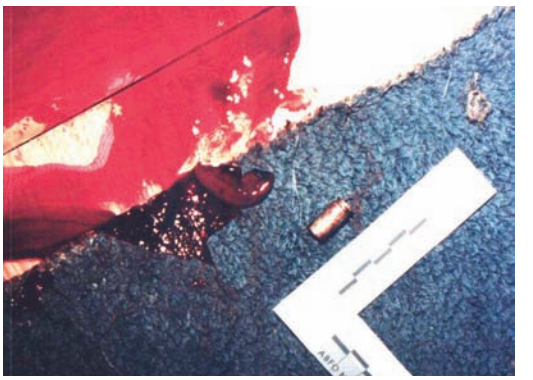

Figure 2.10 A clotted mass on a carpet, laying adjacent to a bullet casing.

Contact Stain

Any stain or pattern created by the transfer of blood from one object to another through physical contact.

Contact stains entail a broad classification of non-spatter stains. They include smears, wipes, swipes, and pattern transfers. See Chapter 3 for a full discussion of the various stains produced by contact.

Directionality

Relating to or indicating the vector a droplet follows in relation to a target.

One of the most important pieces of information available to the analyst is the directionality of the stain in question. Directionality denotes the path or vector the droplet was following at the time it impacted the target.

In spatter type stains, directionality is determined by considering the shape (the ellipse) of the stain in conjunction with any tail or satellite stains created by the impact of the droplet. The directional angle is always parallel to the long axis of the parent stain. Tails, scallops, or satellite stains are deposited on the stain primarily on the side opposite its movement on impact. Figure 2.11 depicts spatter on a floor showing indications of two distinct directions. It is important to distinguish parent stains and satellite spatter; in the latter, the tails actually point back toward their parent.

Directional Angle

The angle, as viewed from the front of the target between the long axis of the stain and a standard reference point (see Figure 2.12).

The directional angle is synonymous with the term gamma angle. This is a measure of the directionality of the stain in relation to the scene and a known reference point (e.g., generally up or north). This measurement is made either to describe directionality in an unam-

Figure 2.11 Spatter on a floor exhibiting two different directions of travel (as indicated by the red arrows).

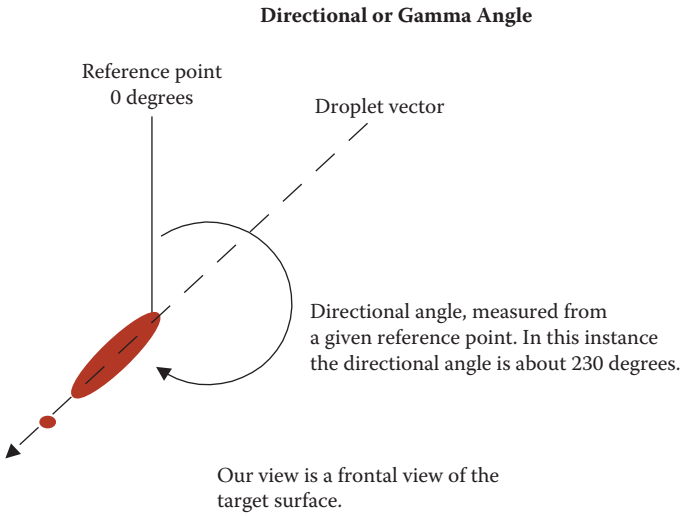

Figure 2.12 Directional angle. This angle describes the directionality, but does so from a standard reference point, thus allowing it to be used by forensic software.

biguous manner for a report (e.g., the stain's directional angle was measured as 230°), or more often for the purpose of defining the flight path using forensic software.

Drip/Drip Trail

Spatter resulting from blood dripping from an individual or otherwise bloodied object. A drip trail is a deposit of a series of drips in linear orientations (see Figure 2.13).

Drip stains and drip trails are specific classifications of pattern types described in Chapter 3. As blood accumulates on an object, small drops form. When the mass/volume reaches a specific point (approximately .08 ml), gravity will overcome the ability of surface tension to hold the drop to the object and the drop will be put into free flight. These drops fall to the ground or other surfaces and produce relatively large spatter stains.

Figure 2.13 A drip trail. Passive drops of blood falling as a function of gravity to a surface can produce drips (randomly oriented stains), a drip trail (a series of stains that lead from one point to another), or a blood into blood pattern as observed in Figure 2.5.

Expectorate Spatter/Blood

Spatter created when blood is forced from the mouth, nose, or respiratory system under pressure (see Figure 2.14).

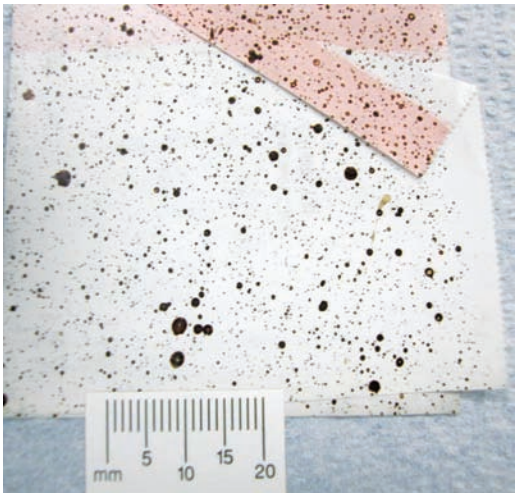

Figure 2.14 Expectorate stains are blood dispersed by some breathing mechanism (e.g., breathing, gasping, or coughing). These stains were produced as a beating victim was face up in the scene and various articles including the receipt were adjacent to the head. Note the small vacuoles in many of the stains.

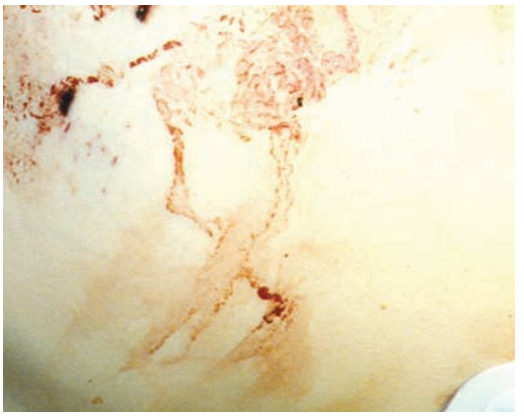

Figure 2.15 A flow pattern on the abdomen of a victim. Flows must follow gravity and they can be quite telling. In this instance, the flow with the distinct dogleg (the top left side of the X) demanded the victim was positioned contrary to the suspect's claims.

Expectorate stains are a specific classification of pattern described in Chapter 3. They result from situations where the mouth, throat, or lungs are injured or when blood is interjected into an air passage and the blood is ejected as a function of breathing.

The mechanical process of breathing acts as a disruption mechanism on the blood in the airway of a living victim. The blood is broken up into relatively small stains. The process is analogous to an atomizer that creates a mist by forcing liquid out using air pressure. Coughing, gasping, and the basic nature of the victim's breathing pattern affect the nature of the air pressure involved, which in turn affects the appearance of the resulting stain. The range of size in expectorate stains can vary greatly, and in some instances expectorate spatter may mimic patterns produced by other spatter-producing actions.

A failure to recognize expectorate blood and its misidentification as spatter from another event can easily cloud the resulting analysis. Although not an absolute rule, expectorate blood may be less vivid in color (from being diluted by saliva), contain vacuoles (where small air bubbles in the stain burst), or contain evidence of mucous strands.

Flow

The movement of liquid blood as a mass under the effect of gravity (see Figure 2.15).

Flows are a specific classification of pattern described in Chapter 3. They are a pattern found at many scenes. Flow patterns are found on the victim, objects, or surfaces in the scene.

Blood flows are created as a function of both active bleeding and passive means. While the heart is still beating, blood is usually forced from the wound irrespective of physical

position. For instance, if the victim is lying on his back with a wound to the chest, blood will be forced to the wound surface by the blood pressure. Once outside the body, gravity takes over resulting in flows down the body.

Once the heart stops beating, body position can prevent gravity from creating additional blood flows. In various positions relative to the wound, the body becomes a container with no mechanism to force the blood upward and out. If, however, the body is repositioned with the wound to the side or down, passive flows resulting from gravity may be extensive. For example, if the body is turned to the side with the wound down, any blood available in the wound drains out as a function of gravity.

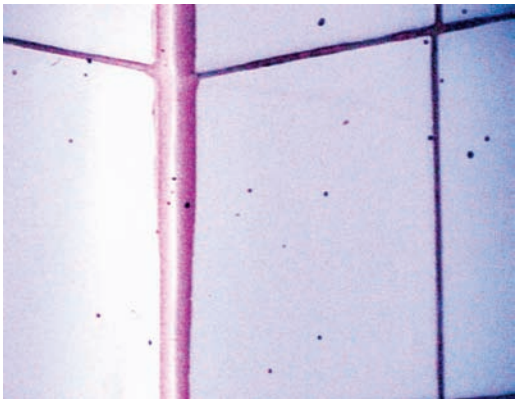

Figure 2.16 A fly spot pattern. Fly spot stains found on the bathroom tile at the scene of a natural death. The decedent lay in the scene undiscovered for some time and fly activity was found throughout the scene. (Photograph courtesy of Detective Mike McGuffey, Covington Police Department, Covington, KY.)

Fly Spot

Stains resulting from fly activity (see Figure 2.16).

The activity of flies in the crime scene will often create post-incident artifacts that on first appearance may appear as spatter. The flies may regurgitate, excrete, or track small amounts of blood onto items within the scene, resulting in such stains.

Impact Site

The point where a given force encounters a blood source.

In discussing bloodstains and their relationship to scenes of crime, references are made to area of origin, impact site, target, or origin. All seem related, but used in specific contexts each have distinct meaning.

Although numerous references are made to drops impacting a surface, an impact site is not the point where a drop impacts. The impact site generally denotes the point on the body or the *location* that receives the force of a blow, resulting in a bloodstain. For example, an injury is received that then bleeds to a secondary surface; should that surface then be struck by some object causing spatter, the second surface is the impact site. No body is involved.

This term is occasionally used to describe the impact point of the drop, referring simply to the point where the drop struck the target, resulting in the observed stain or pattern. Although it is not inaccurate to use the term impact site to denote this point, it often leads to confusion. In discussing such terms, simply ensure that your audience is aware of the "impact site" to which you are referring.

Non-Spatter Stains

Any stain or pattern other than those defined by the spatter group (e.g., patterns not composed of small circular or elliptical shaped stains).

The non-spatter stains are a specific classification of stains/patterns described in Chapter 3. They entail a broad group of patterns that involve contact and both volume accumulations and ejections. Any pattern in which the primary stain is not small, circular, or elliptical shaped is a non-spatter stain.

The two primary sub-categories of non-spatter stains are regular margin and irregular margin. A regular margin is cleanly demarcated and lacks spines or protuberances. An irregular margin involves a jagged boundary or a boundary with numerous spines. (See Chapter 3 for a full discussion and examples.)

Origin/Area of Origin

The area in three-dimensional space from where a blood drop originates.

Origin and impact site are distinct concepts, but in most discussions impact site is the origin. This is the location in 3-dimensional space where a spatter originated.

In the past, this location or origin was referred to as "point of origin." A point suggests a specific position (e.g., a particular x, y, and z position) in 3-dimensional space. In later chapters, as we discuss the methods employed in identifying this location in space, it will be evident that a certain amount of ambiguity exists in identifying the area of origin. In some instances, a relatively effective area of origin can be identified, but in others, the area of origin analysis will simply identify ranges of possible and impossible positions. In describing a distinct area of origin, it may well be identified to an x, y, z point, but it is recognized that this point is the average of the analysis. Thus, it defines an area in space and is now more often referred to as an area of origin.

Parent Stain

The spatter stain from which satellite spatter originates.

When encountering spatter stains at a scene, the analyst is very often concerned with directionality of the stain. To distinguish directionality, the stain being examined must be identified as either a parent spatter/stain or a satellite spatter/stain.

When a drop impacts a target, surface tension, inertia, and velocity all act in their own way to either hold the drop together or break it apart. As it collapses, the surface tension is overcome in the main drop and smaller droplets detach. Both result in stains. The larger stain is the "parent" created by the mass of the blood impacting the target. The smaller stains are secondary spatter thrown off the parent during impact and are generally referred to as "satellite" stains. A parent may spawn multiple satellite stains, but a satellite has only one parent stain (see Figure 2.19).

The primary reason for making a distinction between the two is found in the tail of the stain. Satellite tails point toward the origin, whereas the tail of the parent stain points away from the origin.

Figure 2.17 A pattern transfer on carpet associated with a bloody butcher knife. The knife was placed adjacent to the pattern transfer — after collection of samples and forensic evaluation of both items of evidence — in order to show consistency between the pattern and the weapon. Note the heavy flow along the top edge of the blade toward the tip and the matching saturated area of the pattern transfer.

Figure 2.18 A pattern transfer of a lug-soled boot on the T-shirt of a murder victim. The most common pattern transfers involve hands, feet, shoes, and weapons.

Pattern Transfer

A pattern created by the transfer of blood from one object to another in which a recognizable characteristic or image is present in the pattern.

Pattern transfers are a specific classification of pattern described in Chapter 3. Pattern transfers are one of the most common stains present in any bloodstained scene. This should not be surprising based on the physical nature of liquid blood. Long recognized for its adhesive qualities, once an object is contaminated with blood in some fashion, the blood is difficult to clean up and will tend to contaminate (or stain) anything with which the first object subsequently comes in contact. Figure 2.17 shows the pattern caused by a butcher knife on carpet. Figure 2.18 is the pattern created by a lug sole boot on the back of a victim's T-shirt.

As is evident from the figures, the pattern on the second surface often provides specific characteristics that help the analyst identify the first object. Examples of pattern transfers run a wide gamut, including bloody fingerprints, foot and shoe prints, wiping caused when a weapon (e.g., a knife or bludgeon) is cleaned, and stains caused by the weave or pattern present in bloodied clothing or bedding.

Just as patterned injuries are an important aspect of forensic pathology, so too are pattern transfers to bloodstain analysis. Too often they are simply ignored by the analyst, who fails to see the relationship of the pattern to some other item of evidence.

Primary Stain

The main stain found in any pattern.

In terms of classification, the analyst is concerned with recognizing the main or primary stain characteristics. This is important because many patterns have associated secondary stains present. These can include secondary spatter and spines.

In spatter patterns, the "parent" stains are the primary stains (in other words, the stains produced by the drops that were ejected from the spatter source). In non-spatter stains, the primary stain is generally the largest component of the pattern. For example, in a gush pattern the volume accumulation is the primary stain. This consideration of primary stains is explained in greater detail in Chapter 3.

Ricochet Stain

Blood that impacts an object and then bounces or falls to another target.

Bloodshed in a violent confrontation is a very dynamic situation. We always see the result, but rarely the event. The ricochet stain represents another stain that, if not recognized, can lead to false conclusions.

After impact by a droplet, almost every resulting spatter stain shows its directionality as it struck the target. We should always examine individual stains with some consideration for the possibility of a ricochet.

Satellite Stain/Spatter

Small stains created when droplets detach from a large drop as it impacts a target (refer to Figure 2.19).

When a blood drop strikes a surface at any angle, the drop is subjected to extreme shifts in the liquid. During these shifts, the surface tension acts to contain the liquid as an integral entity. Often, due to the nature of the force involved, this is impossible. During these shifts, smaller droplets may form which are connected to the parent drop by a spine-like structure of blood.

If the velocity of these smaller droplets is sufficient, they may break from the parent, forming a smaller individual stain. Whether these newly formed droplets are attached or detached, one or many, they are the result of a single action and may be classified as satellite spatter.

As stated, the primary difference between satellite and parent drops is that directionality will be opposite in each. Recognizing the satellite and parent relationship, however, is a

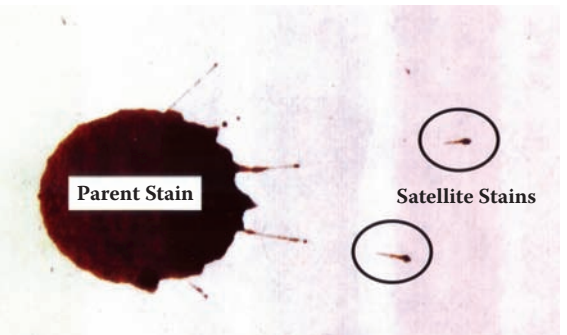

Figure 2.19 A parent stain with several attached and semi-attached satellite stains as well as two detached satellite stains. Note that the tail of a detached satellite points in the opposite direction of tails and spines associated with the parent stain.

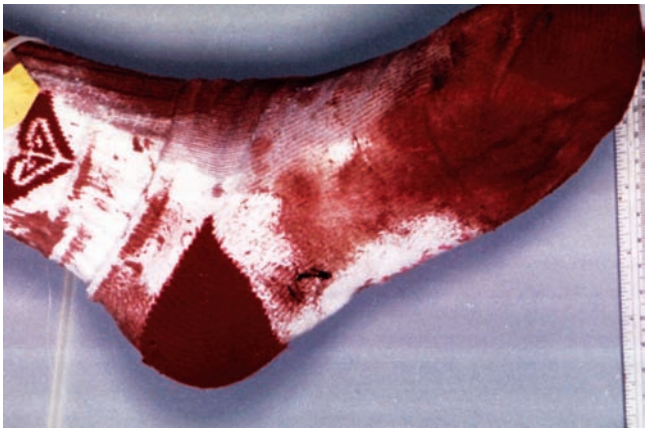

Figure 2.20 A saturation stain on a sock. The location of the saturation along the full length of the top of the sock and lack of full saturation on the bottom assist in positioning the victim when the saturation occurred.

relatively easy process. In overcoming the surface tension of the spine(s), linear tails on either the parent or satellite may be evident. These tails will help in matching parent to satellite.

Saturation Stain

An accumulation of liquid blood created by contact with a volume of blood that is absorbed into a permeable surface (see Figure 2.20).

Saturation stains are a specific classification of pattern described in Chapter 3. More often than not, they serve little or no purpose in the analysis. They typically occur when clothing or fabric items are exposed to blood flows or pools. It is far more likely that a saturation stain will mar other patterns of interest than provide functional information to the analyst. This is a particular problem when a body is placed into a body bag prior to documenting stains observed on the clothing at the scene. In some instances, saturation stains may assist in understanding that a particular item was in contact with the blood source in some fashion.

Shadowing/Ghosting/Void

An area within a generally continuous bloodstain pattern that lacks bloodstains.

If, while a target is being exposed to some form of bloodstain-producing event (e.g., a flow or spatter), a secondary object is either present or introduced between the blood source and the target, the secondary object is likely to receive some of the stains. If either item is then moved from its original position, the remaining target may exhibit some aspect of a void. Beyond its mere presence, this voided area may also exhibit characteristics of size and shape that will help identify the nature of the object that caused it. The terms ghosting or shadowing are used to describe a pattern of this nature, as the voided area casts a "shadow" of the object onto the target.

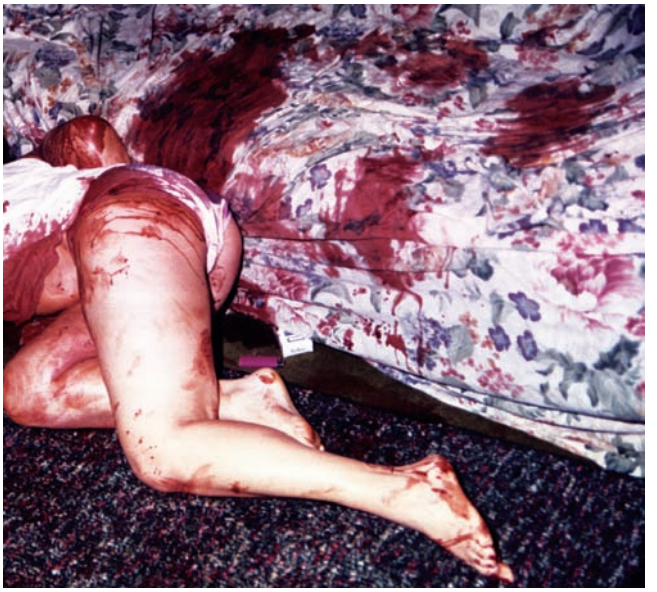

Figure 2.21 A void pattern. While the victim was seated on the couch, a significant blood flow occurred on both sides of her body. After collapsing from the couch, the area protected by the body is quite evident.

At a minimum, the presence of a void indicates some secondary object was involved. The location of the voided area helps place this item (if identified) in the crime scene at the moment of the bloodshed. Depending upon the nature of the event creating the void, its size, shape, or location may provide more specific information. As in the example of Figure 2.21, it is evident that at one point the victim was seated on the couch while a significant blood flow occurred. This type of information helps us place the victims in very specific positions at discrete moments in time.

Because voids occur across many different patterns, they are not described as a basic pattern type in Chapter 3. They are, however, a very specific finding and can be immensely helpful in the analysis.

Skeletonized Stain/Skeletonization

A bloodstain that, although disturbed, still reflects its original shape and size (see Figure 2.22).

Once deposited, blood will usually begin drying from the outer perimeter inward toward the center of the stain. Should the stain be disturbed prior to completion of the drying process, the resulting effect in the outside edge of the stains is referred to as skeletonization. In this effect, those portions of the stain that have dried remain undisturbed, while the wet blood is either wiped away or smeared.

Skeletonization not only helps us recognize the stain's original size and shape, but also helps in sequencing actions. Obviously, it illustrates that some subsequent action has followed the deposit of spatter or stains. It may also provide parameters of the time during which this disturbance occurred.

Figure 2.22 Multiple stains showing skeletonization intermixed in a wipe and partial palm print. The movement of fingers and a hand through the stains disturbed them. The individual claiming to have found the bodies some hours after their deaths stated he became bloody while checking the bodies and moving his hands in this area. A partial palm print in the pattern was identified to this person, but the level of skeletonization disproves his claim as to when this palm print was created. The stains were clearly disturbed soon after they were deposited. (Photograph courtesy of Claire Dawson-Brown, Travis County District Attorney's Office, Austin, TX.)

Smear

Any stain or pattern created by the transfer of blood from one object onto another, through some form of contact involving lateral motion (see Figure 2.23).

Smears are a broad classification of pattern types produced by contact and are described in Chapter 3. Smears include as sub-categories the more defined classifications of wipe and swipe. In most instances, the analyst can distinguish a wipe from a swipe mark, but in situations where this is not possible, the broader group smear is used to describe such a pattern.

Spatter Stains

Those stains resulting from blood that has been put in free flight and subsequently impacted a surface.

Spatter stains are a broad classification of pattern types described in Chapter 3. Small masses of blood that have been put into free flight by whatever means create generally circular or elliptical shaped stains. Although in some venues the term *spatter* is used to describe only those stains associated with dynamic events (e.g., impact spatter), all stains that result from free flight droplets share this elliptical characteristic. Figure 2.19 shows a single spatter stain, demonstrating this elliptical characteristic.

Spatter can be produced by any number of actions including: dispersion at a point source (impact), dispersion from an object in motion (cast-off), breakup of a stream of blood ejected into the air (arterial), and drops that form as a function of gravity (drips).

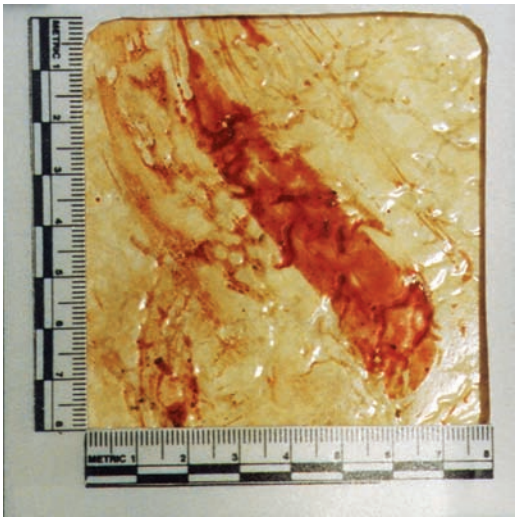

Figure 2.23 A smear pattern. In most instances, smears are differentiated as either wipes (smears of preexisting stains) or swipes (smears of blood onto a surface by another object). If this distinction is not possible or the pattern exhibits both traits, the general term smear is appropriate.

Spatter type stains may be deposited in linear orientations (e.g., cast-off, arterial, drip trails) or non-linear orientations (e.g., impact spatter, expectorate spatter, drips). Examples of patterns made up of spatter type stains include Figure 2.2 (an arterial spurt), Figure 2.9 (a cast-off pattern), Figure 2.13 (a drip trail), and Figure 2.14 (expectorate pattern). For a full discussion of these pattern types refer to Chapter 3.

The size of the spatter is dependent upon a complex interaction of the nature and force associated with the breakup mechanism and the volume available for breakup. As a general rule as we increase the force, the blood breaks up into smaller spatter stains.

Impact spatter, a radiating pattern of spatter, is often of significance to the bloodstain pattern analyst and is discussed in detail in Chapter 8 and Chapter 9. In instances where spatter is produced by impact, the spatter projected outward away from the force or energy is considered to be forward spatter. Spatter that is projected to the rear or back toward the item creating the force is back spatter.

Spines

Linear characteristics evident in both single drop stains and volume stains (see Figure 2.24).

As discussed previously, the surface tension of a liquid is a viable force that attempts to hold the liquid together as a single entity. In the process of overcoming this surface tension, long, narrow spine-like formations form between a parent drop and the secondary droplet attempting to break from it. This spine formation is found in not only the breakup of a single drop of blood, but also when larger quantities of blood are disturbed. When these structures fall to the target they create linear stains referred to as spines.

Large stains that exhibit spines may indicate some measure of force was applied to the blood. A good example is a quantity of blood present on a floor, which is then stomped in by a shod foot.

Figure 2.24 Spines are linear features that are found in a variety of patterns. They occur in large and small volumes of blood. Note the linear features at the tip of the finger pattern transfer.

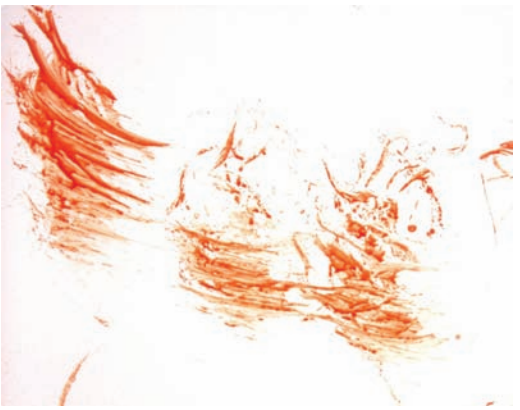

Figure 2.25 A classic swipe pattern created by bloody hair. The lateral motion of the swipe (i.e., the hair is moving left to right) is often evident by examining characteristics such as feathering of the pattern. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

Figure 2.26 Numerous wipe patterns created by the victim's feet moving in a preexisting blood pool.

Swipe

Any stain or pattern created by the transfer of blood from a bloodied object to another by some form of lateral motion (see Figure 2.25).

Wipe

Any stain or pattern created when an object moves through a preexisting bloodstain on another surface.

Swipe and wipe are two specific classifications of patterns produced by contact and are described in detail in Chapter 3. The function of a wipe or swipe in analysis is usually one of sequencing. The first consideration is to distinguish what was bloodied by what (defining the stain as a wipe or swipe). Figure 2.26 shows a wipe caused by the sliding motion of

a foot. Knowing this order may add overall clarity to the events surrounding the incident. Evaluating the nature of the lateral movement also adds to our understanding of the event, very often defining the direction of the movement.

Summary

Language is a fluid and changing medium. This is particularly true for terms used in any technical field. As advances occur in the field, the language evolves to reflect those changes. We have presented a cornucopia of terms. It is not our intent that every analyst must use these terms and only these terms. Certainly, other authors may disagree with the inclusion of some terms in our listing or the exclusion of others.

We hope that by understanding the underlying concepts (which are unlikely to change with time), analysts can express themselves clearly and understand others when discussing any bloodstained scene. In the next chapter, we introduce a specific classification system that further refines and explains many of the terms presented here. Combining the basic terms with an understanding of the pattern classifications presented in the next chapter will provide any analyst a functional vocabulary to utilize and apply to the analysis.

When presenting evidence in court, the analyst may favor a more generic method of phrasing his or her responses, but technical terms are still useful. Ultimately, the analyst is responsible for ensuring that the message they intend to send is received and understood. The specific manner of *how* that is accomplished is best left to the individual analyst to decide.

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Bloodstain Classification

3

A critical step in the application of bloodstain pattern analysis is the classification of the questioned stain or pattern into one of the various groupings (e.g., cast-off, impact spatter, or spurt). Classification is the third step of the bloodstain methodology (see Chapter 4) and involves evaluating and identifying the physical characteristics of the questioned stain without consideration of additional data such as scene context or associated evidence. For example, a classification system might define the criteria of a cast-off pattern as:

- A series of circular or elliptical shaped stains that have consistent directional angles.
- Positioned in a linear or curvilinear orientation.

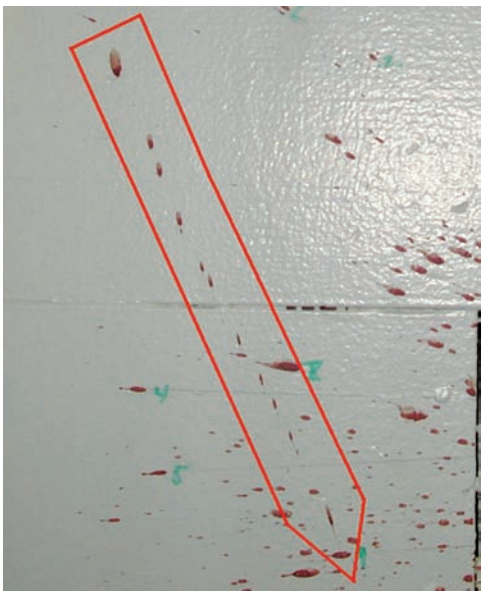

Figure 3.1 Bloodstain pattern analysis considers standard criteria and compares them against a questioned stain. The pattern outlined in red has small circular and elliptical stains deposited in a linear orientation. These criteria help support a classification of cast-off, blood flung from an object in motion.

Thus, when the pattern in Figure 3.1 (outlined in red) is considered against these criteria and meets them it can then be objectively classified as a cast-off pattern. Classification of bloodstains always begins by comparing the physical characteristics of the evident stain or pattern to some established criteria. This evaluation should be a deductive process; the stain meets certain criteria or it does not.

Classification vs. Overall Opinion

Classification is the most important step in the overall bloodstain pattern analysis process. Done properly it sets the stage for any subsequent analytical conclusions. Ultimately, using the classification along with associated evidence and the scene context, the analyst will present a more refined conclusion or opinion regarding the source event. This distinction between the classification (based on physical characteristics) and the analyst's opinion regarding the source event (based on all known information) is a nuance often lost on the novice analyst. For example, consider Figure 3.2. At the scene, the analyst may be presented with large volume drops that have rained down across a surface. The analyst will likely end up with a very general classification, as the pattern is merely spatter type stains with no other true characteristics. That general classification, however, when combined with information such as additional spurt patterns in the scene and evidence of a single arterial

Figure 3.2 It is not uncommon to encounter patterns that have few characteristics. This pattern consists of spatter (drops that have been in free flight). Some of the individual stains appear large. Are they arterial stains that have rained down or simply passive drips? A deductive classification would be to claim the pattern as "spatter stains" and nothing more. This would not prevent the analyst from making a more refined conclusion based on scene context.

wound (stab to the heart), may lead the analyst to provide an opinion that the stains are the result of a particular arterial source. Given the lack of physical characteristics, the classification decision might be tenuous or certainly limited. That does not prevent the analyst from presenting a more defined opinion, after applying inductive logic to the data available. It should be evident, however, that classification (a deductive process) must remain true throughout the inductive argument. For instance, one cannot classify the stain as a flow and then inductively decide it is a smear. The ultimate opinion expressed by the analyst can always become more distinct, but it cannot defy the initial deductive classification.

Classification vs. Definition

It is also important to recognize that classification of patterns is quite distinct from mere definitions of patterns. As discussed, a true classification system sets out some form of criteria to judge the questioned stain against, something that can be compared. Definitions, on the other hand, are just that — a statement of meaning for the word involved. Thus, a definition of cast-off may be presented as "a pattern created when blood is flung or detached from a moving object or an object that has suddenly ceased such motion." As effective as this definition is for understanding the meaning of the word cast-off, it does nothing to explain how the analyst arrived at the conclusion of "cast-off" or what a cast-off pattern looks like. Thus, a classification system must go beyond mere definitions. Most systems of classification in bloodstain pattern analysis are tied to their associated definitions; thus, many classification terms are mechanistic as compared to purely descriptive. Nevertheless, at their heart, each classification system must have recognizable criteria (e.g., shape, volume, orientation, size) to which the questioned stain can be compared and the analyst must be able to articulate these criteria.

The fact that numerous classification systems coexist in bloodstain pattern analysis (and there are several) often confuses those who are new to the discipline, but the differences in

classification systems are simply a matter of perspective. Each classification system starts with some basic issue or perspective (e.g., size of spatter, general mechanisms of creation, or shape of stains). From this point, each system develops along that particular perspective to its various classifications. Every system, no matter what its perspective, ultimately comes back to the same basic pattern types. These include:

- Blood dispersed from a point source by a force (e.g., impact patterns, expectorate)
- Blood ejected over time from an object in motion (e.g., cast-off patterns)
- Blood ejected in volume under pressure (e.g., spurt and gush patterns)
- Blood dispersed through the air as a function of gravity (e.g., drip patterns, drip trails)
- Blood that accumulates or flows on a surface (e.g., pools, flows)
- Blood that is deposited through transfer (e.g., smears, pattern transfers)

These basic pattern types are *reproducible phenomena* and are easily distinguished from one another in most circumstances. However, nothing is ever absolute; keep in mind that there is always the possibility for limitations to be in play that might make classification between even the basic pattern types difficult. Nevertheless, all of the classification systems in use today account for and describe these basic reproducible patterns. How each system arrives at the pattern (the hierarchy described) and the names given the pattern may be slightly different, but every system of classification in effect defines and describes the same result.

If there is confusion in classification, it revolves around how one objectively decides what a particular pattern is. The criteria that each system utilizes to judge the various types of patterns is not always apparent. The majority of these systems fail to articulate clearly what the criteria are and how to objectively pursue an answer to the question: What kind of stain is this? The best system for resolving this failure is a taxonomy.

Why a Taxonomic Classification System?

If we revisit the criteria vs. definition issue, most of the classification systems in use have failed in one sense. In each, a hierarchal flow chart of some nature is present along with effective definitions of the various classifications, but the criteria (that detail for which the analyst must examine a questioned stain) is buried deep in narratives or illustrated through pictures. It is not that each system has not explained in some fashion what an impact pattern looks like as compared to an arterial pattern, but these criteria are not listed effectively and in some cases are ambiguous. This begs the question, how is the practicing analyst able to examine a questioned stain, and what criteria will he or she use when making a classification decision?

A taxonomy is a set of rules for classification. The idea of taxonomy is derived from biology where organisms are classified by shared characteristics. In biology, the various levels of classification (the taxon) are phylum, order, family, genus, and species. The higher the classification taxon (e.g., phylum or order) the broader the classification, with fewer shared characteristics. As one moves down the taxon groups (e.g., family, genus, or species), more characteristics are present and a more refined classification as to the nature of the organism is possible. The criteria reduce the ambiguity in the classification process and provide for a more deductive analysis.

The hierarchical nature of a taxonomy is significant in its application. It reduces subjectivity, as it provides recognizable decision points for the analyst. At the top of the hierarchy are broad categories. Each new level of the hierarchy is a decision point. The analyst examines the

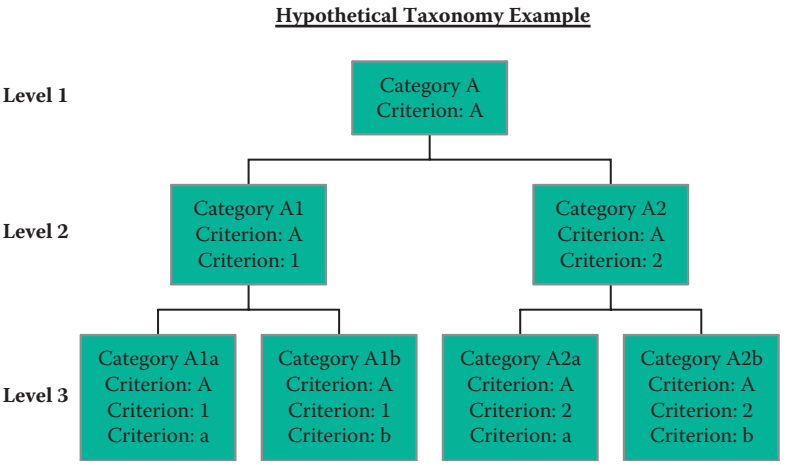

Figure 3.3 A taxonomy is a classification method that consists of categories with various levels and branches. The hierarchy provides a parent-child relationship for the entire classification system, but the associated criteria are what make the categories unique.

item of interest (e.g., an organism or a bloodstain pattern) for the specific criteria listed at each level of the hierarchy. Either the criteria for the classification exist or they do not. If a level is reached where ambiguity exists and no decision is possible, rather than forcing a decision the analyst returns to the preceding parent level where all the requisite criteria were met.

To understand these relationships consider Figure 3.3, a hypothetical hierarchy. All of the items being classified at level 1 share a common characteristic, the criterion "A." Whether the characteristic "A" is present or not is the first decision point. If present, then the item can be considered as a member of the A category. At level 2, the decision point seeks to distinguish two new criteria, "1" and "2." Thus, each category is different from its sibling, but each still shares its common parent's characteristic, the criterion "A." Following the A1 lineage, the next decision point at level 3 looks for two new criteria, "a" or "b." Both children of A1 (A1a and A1b) still share the common characteristics of their parent, the criteria "A" and "1." Each level introduces new criteria; if there are no further criteria to consider, then there is no reason for a new subcategory. Note that categories across the classification system may share characteristics, but each category is itself distinct. The classifier works down the hierarchy, examining each new decision point. When no further decisions can be made, the classification is complete. For example, if the classifier reaches level 3 and for whatever reason no decision can be made, then the classification remains at the level where the last decision was possible (e.g., the prior level of "A1"). In this fashion, the classification (whatever its nature) develops objectively and deductively.

A Taxonomic Classification System for Bloodstains

Up to now a truly taxonomic classification (clearly defined, shared characteristics) system has been absent in bloodstain pattern analysis. James et al. claimed their system to be taxonomic,[1] but they did nothing more than present a new hierarchical format and, like authors before them, buried their criteria in the narrative of their text. As important as the hierarchy is, it alone does not make a system "taxonomic." It is necessary to establish both the parent-sibling relationship of one group to the next (the hierarchy), and to articulate

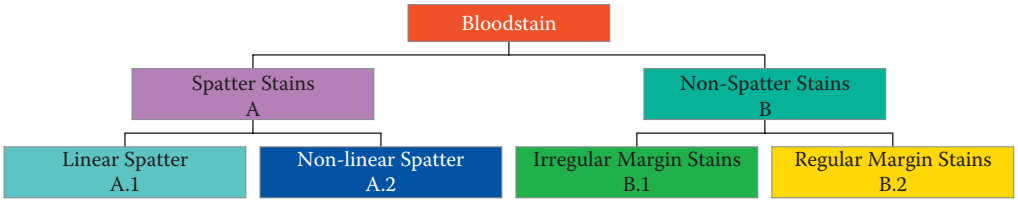

Figure 3.4 The first three levels of the bloodstain taxonomy generate two primary categories (spatter and non-spatter) and four subcategories (linear spatter, non-linear spatter, regular margin stains, and irregular margin stains).

clearly the criteria used at each decision level of the hierarchy. We wish to be clear that in terms of the history of bloodstain pattern analysis, it is not that the pattern criteria do not exist in other systems, they do; but rather they have not been effectively articulated.

In 2002, Ross Gardner first suggested to the FBI's Scientific Workgroup on Bloodstain Pattern Analysis (SWGSTAIN) that a defined taxonomy was needed for bloodstains. SWGSTAIN adopted the idea and the terminology subcommittee became the taxonomy and terminology (T^2) subcommittee. Although writing out these criteria might sound easy enough, from 2002 through 2007 SWGSTAIN has sought to define consensus on these criteria. Although closing in on the mark, it is simply not there yet. The authors offer the following taxonomy as a starting point, realizing that future amendment may be necessary if SWGSTAIN or some other group is able to create a consensus across all of the primary professional groups involved in bloodstain pattern analysis. If consensus were forthcoming, that would be great. But, lacking consensus should not stop each organization or analyst from adopting a clearly articulated classification system for themselves. For without some standard to compare the stain to, in effect any stain can represent anything to anyone.

Figure 3.4 shows the first three levels of the taxonomy hierarchy. The first category is "bloodstain"; thus, the initial decision point is whether the stain in question is blood. As simple as this may seem, it is a recurring consideration for the bloodstain pattern analyst. The next level decision is the spatter/non-spatter issue. The most evident characteristic found in bloodstain patterns is the spatter/non-spatter issue. Have the primary stains been in free flight? A mass of blood that is put into free flight through any mechanism is forced to break up into smaller masses. The resulting free flight droplets (spatter), no matter what their volume, create generally circular or elliptical shaped stains when they impact a surface (see Figure 3.5).

Note that the color and alpha-numeric code associated with each level of the taxonomy will correlate to a decision map, which will be introduced after discussing the taxonomy itself (see Figure 3.34 and Figure 3.41).

The Spatter Family

The criterion for a spatter stain is a generally regular shaped stain with either an elliptical or a circular shape. Before considering the criteria that will be used to classify the various children of "spatter" stains, it is important to consider spatter stain morphology. The primary spatter stain, also known as the parent stain, will have an obvious elliptical or circular shape. Some part or all of the parent stain's outer edge may be marked by a scalloped appearance. Satellite spatter, which is also known as secondary spatter, or wave

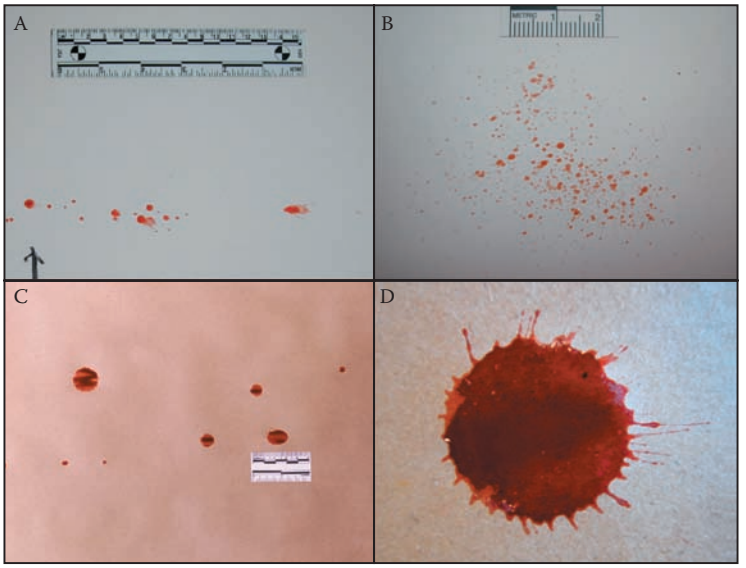

Figure 3.5 Various spatter stains. Pattern A is cast-off. Pattern B is impact spatter. Pattern C is a simple drip trail. Pattern D is single drip. The common characteristic all spatter share is generally elliptical or circular shaped stains, which result from the impact of a free-flight droplet with a surface.

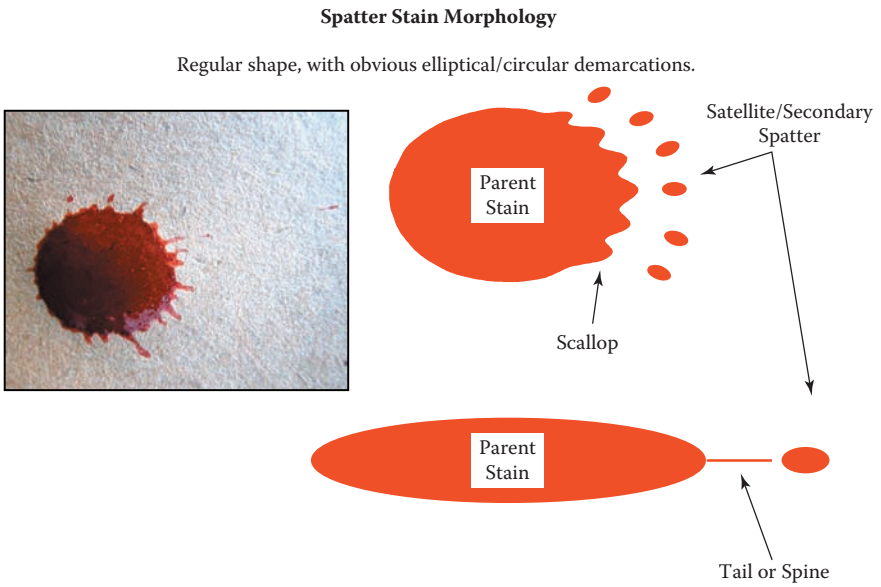

Figure 3.6 Spatter stains demonstrate specific traits (morphology). This includes the circular or elliptical shape, scallops, spines or a tail, and secondary/satellite spatter.

cast-off stains may be present. These satellite spatters were thrown off the parent and associated tails or spines may be present connecting, partially connecting, or pointing from or toward the satellite spatter (see Figure 3.6). These terms effectively allow the analyst to describe aspects of spatter stains. Additional descriptive considerations will include the overall shape and directionality of individual stains.

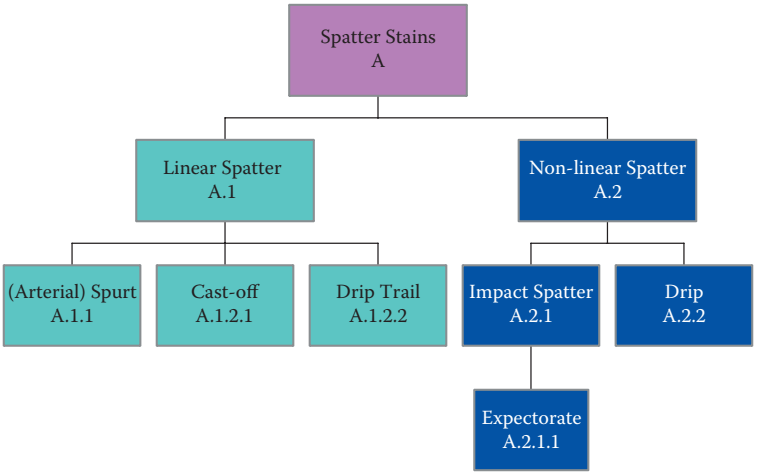

Figure 3.7 The spatter family taxonomy. Note that the lowest level of the taxonomy is divided into the typical terms associated with bloodstain pattern analysis (e.g., spurt, cast-off, drip, impact). The taxonomy does not change the nature of the basic patterns; it simply identifies how we arrive at a given classification.

The taxonomy is organized with the classification category, any preceding family of the category, a general definition, the classification criteria, and a brief discussion of these criteria. The spatter group hierarchy is shown in Figure 3.7.

Category: **Spatter**

Family: Bloodstain
Definition: Stains resulting from blood that has been put in free flight
Criteria:

- Distinct parent stain(s) with circular or elliptical shaped demarcations

Discussion:
The single criterion of a circular or elliptical shaped stain is a function of a mass of blood that has been in free flight and its subsequent collapse on a surface to produce the resulting stain. The parent stains present some form of circular or elliptical aspect, even on some of the roughest target surfaces. These types of stains are found in a variety of dynamically produced patterns as well as gravity-induced drips.

Category: **Linear Spatter**

Family: Bloodstain — Spatter
Definition: A series of related spatter stains dispersed over a surface in a linear orientation
Criteria:

- A series of related spatter stains demonstrating the following:
  - Linear orientation
  - An evident interrelationship in the shape/impact angles
  - An evident interrelationship of the gamma/directional angles

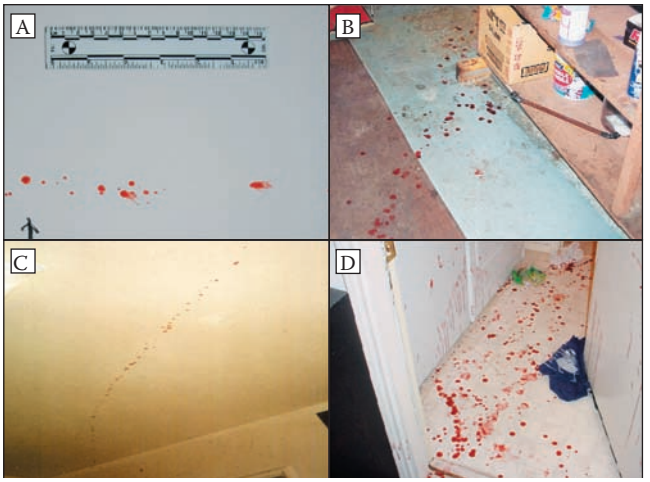

Figure 3.8 Spatter deposited in linear or curvilinear orientations. Pattern A is a cast-off. Pattern B is a drip trail. Pattern C is another cast-off. Pattern D is an arterial event.

Discussion:

The aspect of "related" spatter is evident based on the location, shape, and directional angle of the individual stains being considered. The nature of the directional angles will suggest stains deposited in a radiating or linear fashion. In considering their location, the shape of the stain (its impact angle) will also demonstrate this interrelationship (e.g., gradually increasing or decreasing across the pattern). See Figure 3.8.

Category: **Spurt**

Family: Bloodstain — Spatter — Linear Pattern

Definition: Stains created when blood is ejected in a stream under pressure, most often encountered when an artery or the heart is breached

Criteria:

- A series of related linear spatter stains
- A large volume evident in the individual stains, demonstrated by flows from individual stains or a large volume in the overall pattern
- Any of the following:
  - Large elliptical stains
  - Lines of stains or overlapping stains deposited in Vs, arcs, or a serpentine pattern

Discussion:

The spurt pattern is distinct in that a blood mass is ejected in volume and under pressure as a stream of liquid. Breakup into individual drops is a function of breakup from gravity and air resistance along its flight path, rather than breakup at a point source (impact) or ejection from different points in space (cast-off). Unlike impact spatter where stable droplets are created, breakup of the ejected stream may or may not produce stable drops. More likely are larger unstable (oscillating) drops or masses of blood. When these large volume masses strike a surface, it is not uncommon to see flows out of the individual stains. This flow aspect is quite uncommon in other types of spatter deposition. The ejection itself

Figure 3.9 A spurt pattern. An arc and linear deposition can be observed on the wall to the left. Flows from individual spatter are present in these stains as well. Large volume spatter that fell to the floor can be seen leading to and extending away from the pattern on the wall.

occurs over time but from a point source (the breach on the artery), so even if the source is moving, the drops are deposited in a linear fashion. A rise and fall of pressure in the liquid stream (systolic and diastolic pressure produced by the heart) causes different droplets in the stream of blood to be ejected with different velocity and possibly in a rhythmic fashion. This results in arcs and serpentine patterns (see Figure 3.9). The change of the stream's orientation to the target also presents diversity in appearance. Note that in Figure 3.9, where the drops strike the vertical surface, the drops show an evident arc. On the floor at both ends of the arc pattern is a continuation of the arterial pattern, but because the droplets are moving downward, they appear much like a trail of blood. When large volumes are ejected, they may follow similar flight paths, so it is not uncommon to have several masses strike near, simultaneous, beside, or on top of one another. The combined volume acts similar to a single droplet and creates large elliptical stains (see Figure 3.10). Spurts are most often associated with arterial events, when a breach of an artery or the heart occurs while the circulatory system is still under pressure.

Figure 3.10 Large elliptical stains are found in spurts as well. These occur when a large mass of blood impacts a surface, or multiple individual spatter drops impact at the same time. (Photograph courtesy of Steven Chancellor, United States Army Criminal Investigation Command and Donald R. Schuessler, Department of Public Safety, Eugene, OR.)

Category: **Cast-Off**

Family: Bloodstain — Spatter — Linear Pattern

Definition: Stains created when blood is flung or projected from an object that is in motion or suddenly stops some motion

Criteria:

- A series of related linear spatter stains
- Deposited in a linear or curvilinear orientation
- With consistent parallel directional angles in the stains to the overall pattern
- A consistent change in impact angle in the pattern

Discussion:

Blood on an object is put into accelerated motion when the object itself is moved. Individual droplets are ejected from the object over time; thus, the droplets are ejected at various points along its path (often referred to as swing cast-off). As a result, stains are deposited in lines (straight, curved, or combinations). Note that this linear aspect may include stains that are in line, one after the other, or a series of stains deposited in broad lines (see Figure 3.11). As the droplets were ejected in the same direction (either a forward or backward swing), the directional angles of the individual stains are consistent as well and follow the general direction of the overall pattern. For example in Figure 3.12, at A1 the directional angles (annotated by the red line) are left to right and slightly upward. The arc of the swing became more upward further along the path, so at A2 the directional angles are angled significantly upward to the top of the picture. This parallel aspect does not mean the directional angles are always "in line" with the overall path, as this interplay is very dynamic; rather, it indicates a consistency of the directional angle in reference to the overall path of the pattern.

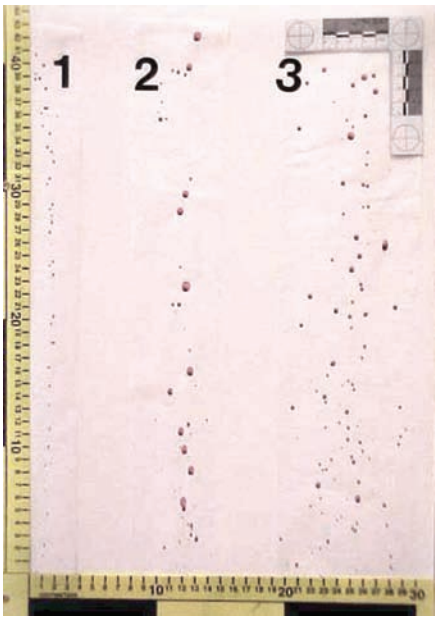

Figure 3.11 Three different cast-off patterns produced by three events. The first was created by swinging an edged weapon, the second with a bat, and the third with a piece of lumber.

A critical distinction between the cast-off pattern and its sibling the drip trail is the change in impact angle. A cast-off pattern will always reflect either increasing or decreasing impact angles across the pattern, whereas impact angles in a drip trail may remain consistent or alter back and forth as a function of changing momentum of the object from which they are dripping. For instance, in Figure 3.12 the stains become more elliptical as one moves to the right in the pattern. This characteristic is always considered relative to a single surface (e.g., a given floor or wall), for as the cast-off crosses from one surface to the next, the impact angles will obviously alter.

A form of cast-off pattern is also produced when a bloody object ceases some

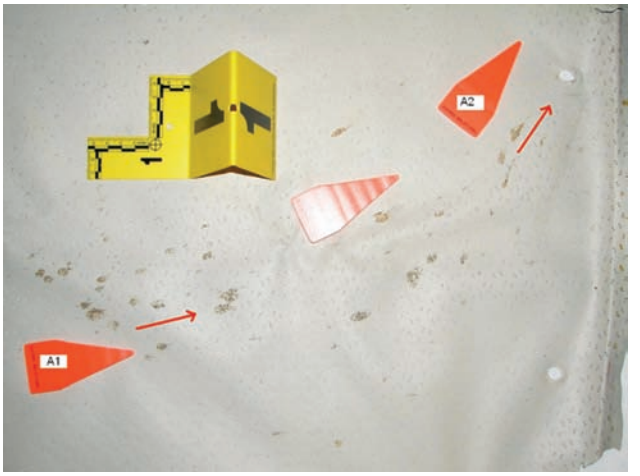

Figure 3.12 A distinct characteristic of a cast-off pattern is that because the drops are ejected at different times from the object in motion, their directional angles (gamma angle) will change over time to follow the change in direction of the object. Note the change in directional angle between A1 and A2.

motion. Such stains are referred to as cessation cast-off. Cessation cast-off generally does not display the same characteristics as swing cast-off. It may or may not appear in a linear orientation, but may also demonstrate a limited radiating effect. The reason for this is that when the motion ceases, the object stops its movement, perhaps incompletely, but enough to remove the distinct linear aspect seen in swing cast-off caused by transition of the swinging object. A cessation cast-off pattern is more likely to appear as spatter ejected from a point source. For that reason, spatter stains associated with forward cessation cast-off may be completely lost in impact spatter. In rearward swings, they may appear on any surface (to include the backs of individuals swinging items). Because there are no specific characteristics associated with cessation cast-off when encountered, such patterns would most likely be described and classified as non-linear spatter (classification A.2).

Cast-off patterns can be the product of offensive actions (e.g., the swinging of weapons), but they may also occur from defensive behavior (e.g., bloody hands or appendages in motion).

Category: **Drip Trail**

Family: Bloodstain — Spatter — Linear Pattern

Definition: A pattern of individual spatter deposited on a surface, demonstrating movement of the dripping item from one point to another

Criteria:

- In-line distribution of spatter stains
- Consistent stain size range in the pattern, relative to any change in surface characteristics or decreasing volume available to produce the drip
- Stains lead from one point to another
- Stains will typically range in size between 3 to 25 mm

Discussion:

The spatter family is produced by some form of breakup (e.g., external impact, ejected under pressure, gravity, or put in accelerated motion). In spatter produced by dynamic events such as impact and accelerated motion, the cohesive forces are overcome more easily by the interplay of the disruptive force, producing smaller volume droplets. This, in turn, produces smaller diameter stains. In drips, the only force acting to counter the cohesive forces is gravity. Gravity is a weak force, so the cohesive forces are not overcome as quickly. This allows a greater volume of blood to accumulate before a droplet detaches from the blood mass. As a result, the droplets tend to be of a larger volume and the resulting stains of a greater diameter. A number of issues define the size range of the resulting stains. These include speed of the falling drop before impact, surface area on which the drop accumulates, and the absorbency of the target. A typical "stable" drop is on the order of approximately .05 ml (although slightly larger droplets are possible), which produces a free flight droplet with a diameter of about 5 to 5.5 mm. This size of drop has the potential to create stains with diameters of approximately 14 mm in size. If, however, the drip forms on a large surface area the size of the drop, and thus the stain, can be larger. It is not uncommon to see drips from broad objects that measure 20 to 25 mm in size. On the other end of the spectrum, studies suggest that the smallest parent stain produced as a function of a drip is no smaller than 3.5 mm.[2] This figure is a function of the minimum volume of blood that must accumulate on any surface before gravity will overcome the cohesive forces. This volume is approximately .008 ml.

A blood trail is simply a deposit of drops of varying sizes, as described above, from one point to another. If resulting from a single source event (e.g., a bloodied weapon being moved, a bleeding victim moving), the size range evident in the series of spatter will generally be consistent relative to surface characteristics. As the drops fall to various targets (e.g., hard wood in a hallway, then onto carpet in a living room) the size may change. For example, in Figure 3.13, the victim source was dripping blood onto the welcome mat and the concrete. The drop volume was not changing, but note that the drips on the different surfaces appear quite distinct in size. This is nothing more than a function of different

Figure 3.13 A drip across multiple targets. A drip event deposited stains onto the concrete and the door mat. Note the dramatic size change between the stains deposited on the concrete and the carpet. The primary difference in size is not associated with the volume of the drip, but rather with the nature of the target surface.

Figure 3.14 To be a drip trail, the stains must be deposited in a linear fashion that leads from one point to another.

target surfaces (one absorbent, one not). For a non-replenishing source such as a bloodied object, the size range will ultimately decrease over time. For a replenishing source such as a bleeding victim, the size range should remain generally the same throughout the pattern. Size range considerations must also allow for some variation due to falling height. The further a droplet falls, the faster it falls up to its terminal velocity. This increase in speed increases the size of the resulting stain as well. Therefore, if a significant change in the dropping height occurs, the pattern will reflect that change in spatter size up to a maximum defined by the volume. Obviously, for the pattern to be a trail, it must lead from some point to another as in Figure 3.14.

In differentiating the drip trail from a cast-off pattern, note that in the drip trail the impact angles reflected across the pattern can remain generally the same, or they may increase and decrease as a function of the speed at which the dripping object moves. For instance, in Figure 3.14 the stains all appear round. Cast-off patterns always reflect a consistently changing impact angle.

Category: **Non-Linear Spatter**

Family: Bloodstain — Spatter

Definition: A series of related spatter stains dispersed over a surface other than in a linear orientation

Criteria:

- A series of related spatter stains demonstrating the following:
  - An evident interrelationship in the shape/impact angles
  - An evident interrelationship of the gamma/directional angles
  - Non-linear orientation

Discussion:

Non-linear spatter is the second category of spatter (see Figure 3.15). The aspect of "related" spatter is evident based on the location, shape, and directional angle of the individual stains being considered. The nature of the directional angles will definitely suggest stains deposited in a radiating fashion. In considering their location, the shape of the stain will also

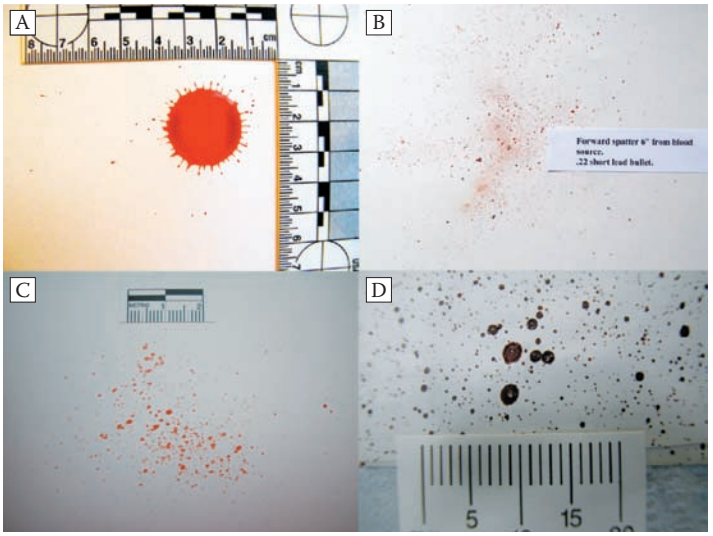

Figure 3.15 Various forms of non-linear spatter.

demonstrate this interrelationship. Across the distributed stains in the pattern, the shape of the stains will change in a predictable fashion based on their different angles of impact.

Category: **Impact Pattern**

Family: Bloodstain — Spatter — Non-linear Pattern

Definition: A radiating pattern of small individual drops created when a blood source is broken up at a source by some force

Criteria:

- A series of related small spatter stains
- Deposited in a pattern that has a radiating distribution in some fashion
- Progressive change in individual stain shape the further out in the pattern
- Various size range of parent stains, but generally consistent throughout the pattern

Discussion:

The radiating spatter pattern results from a mass of blood broken up at a point/area source by some force (e.g., gunshot, blunt force). As a result, the mass of blood available breaks up into stable droplets (typical stable impact droplets are no greater than 2 mm in diameter[3,4]). These droplets are ejected into the scene, resulting in small stains typically 5 mm or smaller. It is recognized that larger stains may occur, but the preponderant size range of impact spatter will generally be 5 mm or smaller.

As a force contacts a blood mass, it is incompressible and the blood seeks a path of ejection along whatever avenue is available (see Figure 3.16). Thus, the dispersion cone of spatter created by the impact may radiate out in a very broad fashion (e.g., ejected in a 360° circle all around the point source) or in a focused fashion (e.g., in a 10° arc). A number of variables may affect this dispersion. These include, but are not limited to, avenue of escape, shape of the wound, and clothing or hair. The directional angles of the individual stains when considered together will show this radiating effect (see Figure 3.17).

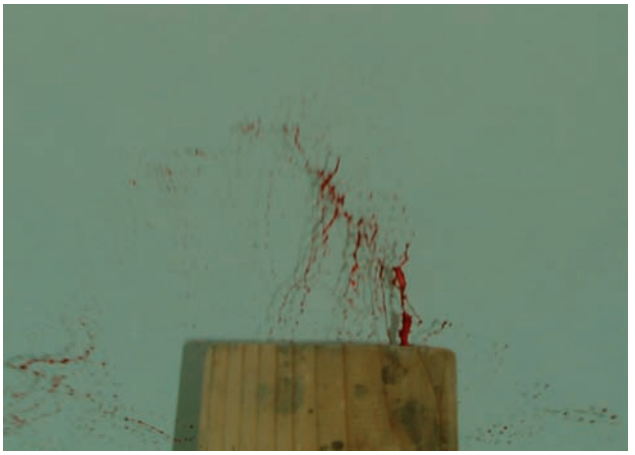

Figure 3.16 Impact spatter radiates out from a central area. In this impact, the drops can be seen ejecting forward along the leading edge (350° to 20°), to the left (270° to 290°) and to the right (80° to 90°).

Figure 3.17 The resulting pattern created by the impact observed in Figure 3.16. Note the primary pattern radiates outward from the ejection point. Not all of the stains on the right and left are captured in the photo (they carried to the side walls), but some stains are visible showing the full cone of ejection.

The more acute the angle of impact between the event and the target, the more evident and dramatic the radiating distribution will be. If the event directs spatter at a more perpendicular angle (e.g., 70° to 90°) to the target, this radiating distribution is more subtle and difficult to visualize. It can still be recognized by considering the directional and impact angles of the individual spatter stains.

Category: Expectorate Spatter

Family: Bloodstain — Spatter — Non-linear Spatter — Impact

Definition: Spatter created when blood is forced from the mouth, nose, or respiratory system under pressure

Criteria:

- A series of related spatter stains
- Varying range of size in the individual spatter
- Possible dilution of color in the stain
- Any of the following:
  - Presence of air vacuoles (bubble rings)
  - Mucous strands
  - Presence of epithelial cells or other chemical properties supporting a respiratory source (e.g., amylase)

Discussion:

When an injury occurs to the airway (e.g., mouth, trachea, lungs), or when blood is injected into the airway (e.g., swallowed or drains in some fashion), and the victim is capable of breathing out, spatter is often created. Much like an atomizer breaks up perfume with air pressure, the act of breathing out breaks up the blood into droplets that are ejected into the scene. The term used to describe these stains is expiratory or expectorate. They are not aspirated blood, as they are ejected *from* the body, not aspirated into the body. Air vacuoles are the most specific criteria used to support an expectorate event. Air and blood often mix in the airway and small air bubbles are ejected along with the liquid. When the bubbles burst, they leave behind ringlets or vacuoles in the stains. These small ringlets may appear in a few or many of the resulting spatter stains (see Figure 3.18). The size range of the stains found in any expectorate event can vary dramatically. First, the size range may vary as a function of the nature of breathing. If the victim is gasping and ejecting large volumes of blood, the size of the resulting spatter is likely to be large. If, however, the victim is able to breathe forcefully, the spatter may be very small. The second factor for size is that the nature of breathing may alter over the course of an event (e.g., forceful breathing in the beginning, followed by choking and gasping at a later point), so a combination of both large and small spatter may result. Additional supporting criteria of expectorate spatter include an evident dilution of the stain as a function of the blood mixing with saliva. Keep in mind that a diluted effect is not limited only to expectorate events, as dilution may appear in impact spatter from head wounds where the spatter is a mix of blood and cranial fluid. A related characteristic for expectorate spatter is mucous strands, connective strands between small spatter caused by saliva (see Figure 3.19). There are a number of additional supporting criteria

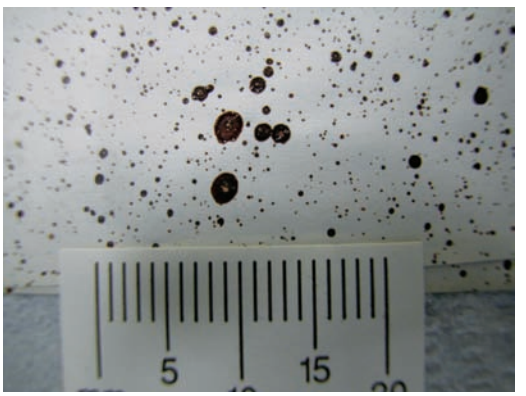

Figure 3.18 Expectorate stains on paper. Note the small circular vacuoles in many of the individual spatter stains. These form after air bubbles mix with the blood in the airway, the stains are dispersed, and the bubbles burst.

that may aid the analyst in isolating the spatter to the expectorate category. These include the presence of epithelial cells and various chemical compounds associated with the mouth or respiratory system. The most common of these is amylase. However, these criteria are identified through subsequent serological examinations.

Expectorate is often problematic. The ringlets may not remain on absorbent targets and dilution or mucous strands are not always present. The ultimate conclusion (not classification) regarding a stain as expectorate is very much a function of scene context. A basic consideration at the scene and autopsy is to look for blood in the victim's mouth, airway, or lungs. If there is no evidence of blood in the airways, this generally precludes expectorate. Lacking vacuoles or one of the other supporting criteria it may be difficult to distinguish a pattern produced by expectoration from impact patterns.

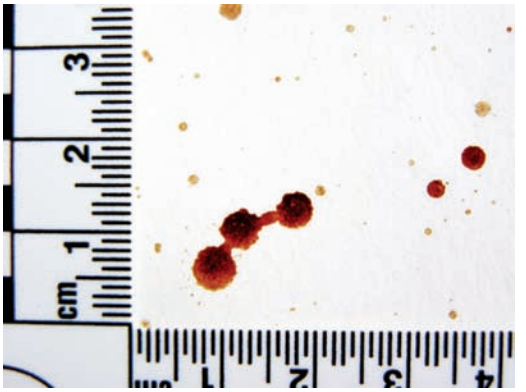

Figure 3.19 Mucous strands that connect various spatter stains are another common characteristic found in expiratory spatter.

Category: **Drips**

Family: Bloodstain — Spatter — Non-linear Pattern

Definition: Spatter resulting from blood dripping from an individual or otherwise bloodied object

Criteria:

- One or more spatter stains
- Parent stains have a generally large diameter (typically 3 to 25 mm)
- Randomly oriented on a surface

Discussion:

As discussed for drip trails, drips are produced as a function of gravity acting on the blood source. Allowing for some variation, drip stains should range in size between 3 and 25 mm in diameter (see Figure 3.20). This range provides a helpful criterion against which to gauge spatter stains. If the analyst encounters parent stains under 3 mm, they are most likely some form of dynamic spatter (e.g., impact, expectorate), and if the analyst encounters stains in excess of 25 mm, they are less likely to be stains produced by drips, but rather created by a larger mass of blood (e.g., ejected volumes such as arterial).

Figure 3.20 Stain size of passive drips can vary greatly. Parent stains will typically range from 3 mm to approximately 25 mm. These drips were produced by a victim who suffered several gunshot injuries and then stood behind the door in the corner.

Drip stains, when deposited in number, have a random orientation on the target unless they are deposited in lines as previously described (e.g., a classification of drip trail). Their associated impact angles will reflect their downward paths, but minor variation may be evident due to random movement of the object on which the drip formed.

One caution regarding this category is the so-called gravity stain. In our terms, gravity stains are produced by droplets that have lost energy and have fallen to a horizontal surface resulting in randomly oriented round spatter stains of various sizes. Examples might include what Wonder referred to as arterial rain or impact spatter that has been projected a distance and landed on a horizontal surface.[5] The more predictable characteristics of radiating patterns or evident flows from individual stains may be lost in this instance. Presented with an ambiguous pattern of this nature, the more effective classification is the general category of non-linear pattern.

The Non-Spatter Family

The second primary category of the taxonomy is the non-spatter group. This group includes stains and patterns where the *primary stain* is not spatter; in other words, stains and patterns produced by other than free flight droplets. This does not mean the non-spatter patterns do not include *any* spatter stains. On the contrary, satellite stains and secondary spatter produced by various mechanisms (e.g., volume ejections striking a surface) may be present in this group. The primary stains, however, will not be small circular or elliptical stains.

In discussing such stains, some basic morphology is necessary. Rather than elliptical or circular stains, the stains of the non-spatter group are marked by shapes with no obvious symmetrical ellipse or circular component. They may have a contiguous boundary that encloses the entire stain or part of the stain. The boundary or margin of the stain may be regular or irregular in nature. Striations (small linear features) may be evident in the stain where the blood has been disrupted. Some portion of the stain's boundary may be feathered as well (see Figure 3.21). This group is composed of a wide range of stains that can be difficult to describe. The non-spatter hierarchy is depicted in Figure 3.22.

Category: **Non-Spatter**

Family: Bloodstain

Definition: Any stain or pattern other than those defined by the spatter group

Criteria:

- A primary stain with no evident elliptical or circular component

Discussion:

This group entails stains from three primary mechanisms: contact, accumulations of blood, and ejections of large volumes. Although blood accumulations such as pools may have a circular component, that characteristic is clearly an obvious distinction from small circular spatter stains. The appearances of the non-spatter stains are so diverse at the next level

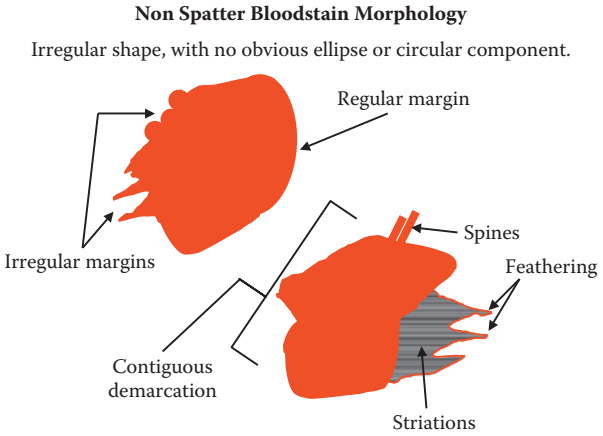

Figure 3.21 Non-spatter stains demonstrate specific traits (morphology). This includes parent stains that have a shape other than an ellipse or circle, feathering of the edges of the stain, striations in the body of the stain, spines, and even secondary spatter.

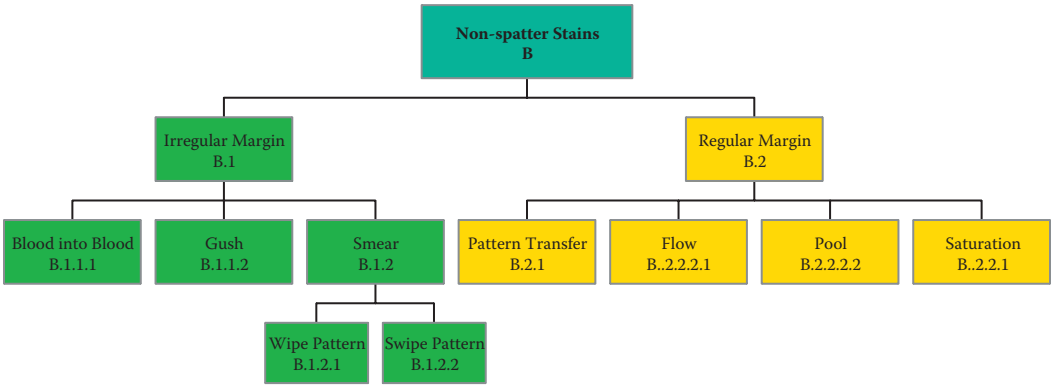

Figure 3.22 The non-spatter taxonomy relationships. Once again, if we examine the lower levels of the taxonomy, we find standard pattern types (e.g., wipes, swipes, pattern transfers, gush, and blood into blood).

of the taxonomy that it is atypical to encounter a stain that cannot be classified beyond this primary level of "non-spatter."

Category: Irregular Margin

Family: Bloodstain — Non-Spatter
Definition: A stain with an irregular or spiny margin
Criteria:

- A non-spatter primary stain
- Irregular or spiny margin

Discussion:
This group includes large volume ejections, fluids dripping into fluids (e.g., blood into blood) that subsequently accumulate on a surface, and various contact stains. In the first,

the interaction of the large volume with the surface produces the irregular aspect as well as numerous spines and radiating secondary spatter. In the second, the dripping action into the accumulating pool produces the irregular aspect. In the last, the interaction of the two objects in contact produces the irregular characteristics (e.g., feathering, striations).

Category: Gush/Splash

Family: Bloodstain — Non-Spatter — Irregular Margin
Definition: An irregular pattern created when blood is ejected in volume
Criteria:

- A large volume accumulation evident in the overall pattern
- Large irregular stain exhibiting spines and spatter radiating from it
- Large elliptical spatter stains around the pattern

Discussion:

Where the spurt is a discrete pattern created by a distinct stream of blood, the gush is a very large volume ejection pattern. This large volume is ejected under pressure, but more as a mass than as a stream. On impact, the resulting mass can produce large primary stains, as well as numerous satellite spatter and spine-like stains radiating out from the primary stain (see Figure 3.23). The large mass is unstable in flight and is acted on by air resistance and gravity, which often results in smaller unstable masses of blood that separate from the primary volume before impact. These smaller masses will produce large elliptical stains around the periphery of the primary pattern.

A point of interest with the gush category is the inclusion of less forceful ejections in the category. As the pressure behind the ejection is reduced, the result is fewer spines and secondary spatter. This type of pattern is often called a splash by other classification systems. The primary difference between the two patterns is a function of force, something the analyst can never measure. Thus, the analyst is presented with a classification problem that cannot be resolved. How many spines or secondary spatter must be present to define

Figure 3.23 A gush pattern. A gush is a large volume deposit with spines and secondary spatter in and around the periphery creating a very irregular or spiny margin. This gush was created by a gunshot injury to the femoral artery.

a gush vs. a splash? Both patterns exhibit spines and secondary spatter. The only observable difference in the patterns are the number and length of the spines and the number of secondary spatter. Beyond that, any splash looks like a low force gush. If the analyst cannot objectively articulate a point where the patterns are different, then the only valid resolution in our minds is to keep them in the same category.

Category: **Blood into Blood**

Family: Bloodstain — Non-Spatter — Irregular Margin

Definition: Drips deposited into one another or into another stain or another liquid, resulting in an accumulation and secondary spatter randomly oriented around the stain

Criteria:

- A pooling of blood or some combination of blood and liquid exhibiting overlapping drips or spines
- Surrounded by a random distribution of small satellite spatter
- The satellite spatter will show random variation in its directional angles and shapes

Discussion:

A blood into blood pattern is produced when drops fall into another stain and a volume accumulates on the target. The impact of the drop into the liquid on the target results in a significant increase of secondary spatter. The boundary becomes irregular as a function of drips falling and overlapping each other, as well as spines ejecting from the pool. Because of the relative motion of the liquid on the target (it may be rolling or oscillating), this secondary spatter is ejected in random directions out from the primary pool or stain. These small satellites often impact on top of one another as well, resulting in coalesced drops that have irregular shapes (see Figure 3.24). Thus, they will differ distinctly from the spatter/stains observed in impact spatter events.

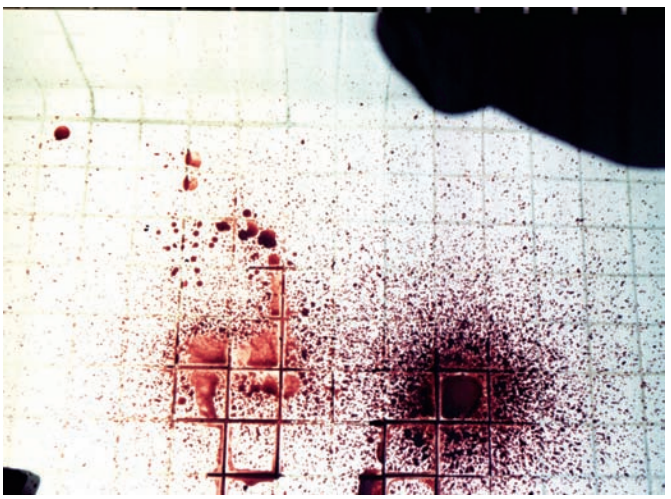

Figure 3.24 Another non-spatter volume pattern is the blood into blood pattern. It too has an irregular margin. An associated characteristic of the blood into blood pattern is the random distribution of irregular shaped spatter around the parent stain.

Figure 3.25 An interesting feature of blood into blood is that in some instances the primary stain can be disassociated from the irregular spatter. In this instance, the parent stain (the accumulation) was on the shoe. When the subject walked away, the shoe left only the random irregular spatter in the scene.

The analyst should keep in mind that the satellite spatter produced by these patterns might be disassociated from the primary stain. For instance, the pooling may occur on the top of a shoe, with the satellite spatter being ejected onto the surrounding floor. When the shoe walks away with the wearer, all that is left is the random distribution of satellites (see Figure 3.25). In such an instance, the spatter may be classified as some general form of spatter (e.g., a non-linear pattern). Recognizing the subtle differences between the random arrangement and irregular shape of the satellite spatter and the radiating pattern found in impact spatter is important for the ultimate conclusions.

Category: **Smear**

Family: Bloodstain — Non-Spatter — Irregular Margin

Definition: Any stain or pattern created by the transfer of blood from one object onto another, through some form of contact involving lateral motion

Criteria:

- An irregular shaped contact stain demonstrating any of the following:
  - A contiguous boundary
  - A feathered boundary
  - Striations in the body of the stain
  - Diminished volume of blood across the body of the stain
  - Evident displacement of blood

Discussion:

The smear entails a contact stain with an irregular shape, where there is evident motion between the objects in contact with one another. Thus, the stain may reflect various combinations of contiguous and feathered edges along its boundary. The lateral motion

between the objects displaces the blood, resulting in striations across the primary stain. The combination of this lateral motion and contact may distinctly displace the blood from the boundary, forcing it into the edges, or it may leave a thin veneer of blood across the surface. Another aspect of the smear is a diminished volume of blood across the stain, where the available blood is deposited heavily at first, but as the contact continues there is less blood to be left behind. In many instances, a smear can be further classified as either a wipe or swipe.

Category: Wipe

Family: Bloodstain — Non-Spatter — Irregular Margin — Smear
Definition: Any stain or pattern created when an object moves through a pre-existing bloodstain on another surface

Criteria:

- A smear stain
- A preexisting volume of blood (e.g., flow, spatter, pool)
- Displaced blood from the original boundary
- Any of the following:
  - A feathered boundary
  - Striations in the body of the stain
  - Diminished volume of blood across the body of the stain
  - Accumulation of blood on the other boundaries
  - Dried outer ring (skeletonization) of the original stain

Discussion:
The wipe involves disrupting a pre-existing stain of some nature through lateral motion and contact by another object. Thus, the pre-existing stain will be evident, as well as the disruption and displacement of the blood. The disruption may show striations, feathered edges, or displacement of blood into the outer edges of the stain. The original stain boundary (the stain being disrupted) may or may not demonstrate a dried outer ring, known as skeletonization. This depends upon the amount of time that passed after the original deposit and the subsequent disruption (see Figure 3.26).

Category: Swipe

Family: Bloodstain — Non-Spatter — Irregular Margin — Smear
Definition: Any stain or pattern created by the transfer of blood from a bloodied object onto another by some form of lateral motion

Criteria:

- A smear stain
- With a contiguous boundary on one side and any of the following:
  - A feathered boundary
  - Striations in the body of the stain
  - Diminished volume of blood across the body of the stain
  - Accumulation of blood on the other boundaries

Figure 3.26 A wipe pattern. The existence of the pre-existing stain is a significant characteristic. Here a volume of blood accumulated on the floor and was then disturbed.

Figure 3.27 A swipe pattern. This blood was deposited when a bloody object made contact with the ceramic surface. Note the characteristics of striations in the body of the stains and some feathering in the right boundary.

Discussion:

The swipe is specific in that it shows that a bloodied object was in motion and deposited the stain onto a second surface. This is in contrast to the wipe where there was a pre-existing stain that was disrupted by something. The point of contact is often defined by a contiguous boundary and the side opposite this boundary may reflect any of the characteristics described: a feathered appearance, striations, accumulation of blood on the other boundaries, or diminished blood across the body of the stain.[6] See Figure 3.27.

Category: Regular Margin

Family: Bloodstain — Non-Spatter
Definition: A stain with a regular/distinct demarcated margin
Criteria:

- A non-spatter primary stain
- Regular margin (e.g., cleanly demarcated edges)

Discussion:
This group includes volume accumulations where liquid blood is pooling or flowing in some form, as well as situations where patterns produced by contact result in some observable regularity (a pattern).

Category: Pattern Transfer

Family: Bloodstain — Non-Spatter — Regular Margin
Definition: Any stain or pattern created by the transfer of blood from one object to another in which a recognizable characteristic or image is present in the pattern

Criteria:

- A contact pattern
- Demonstrating angular demarcations, curves, or other recognizable characteristics or an image of the source object
- May be deposited in a series

Discussion:
Pattern transfers are contact stains that usually involve limited motion. As a result, they leave characteristics or a 2-dimensional image of the bloodied surface that created them. The pattern itself produces the regular margin affect. They can be distinct as in the case of a knife blade or footmark; or they may be vague at best showing distinct angular demarcations indicating some object was the source, but not allowing sufficient characteristics for recognition of the object (see Figure 3.28).

Repetitive pattern transfers are a series of similar pattern transfers, deposited over time on a surface or surfaces. Some may be patent (visible), while others are latent and must be enhanced chemically to view. Individual patterns may not be exact matches of one another and may reflect various characteristics of the object that made them. This is a function of the object making contact with the surface in different orientations (see Figure 3.29).

Figure 3.28 A pattern transfer on a T-shirt. A bloody hand made contact with the victim's shoulder, leaving behind a light pattern transfer.

Category: Pool

Family: Bloodstain — Non-Spatter — Regular Margin
Definition: An accumulation of liquid blood based on gravity and conforming to container characteristics of the pooling area

Figure 3.29 A repetitive pattern transfer. Multiple finger marks on a cup from a crime scene. Repetitive marks encountered at a crime scene may include shoes, feet, hands, or weapons.

Criteria:

- A clearly demarcated non-spatter stain with regular margins
- Evident volume accumulated
- Without specific shape, but conforming to surface contours
- May demonstrate serum separation and or clotting

Discussion:

Pools can form in a variety of fashions and on any number of surfaces; thus, their specific shape is a function of where they form. They will have a distinct liquid boundary, contain some volume, and may show a separation of the blood cells from the plasma (serum separation). See Figure 3.30.

Figure 3.30 A pool with evident serum separation. The straw-colored fluid at the lower right side of the pool is serum.

Category: **Saturation**

Family: Bloodstain — Non-Spatter — Regular Margin

Definition: An accumulation of liquid blood created by contact with a volume of blood that is absorbed into a permeable surface

Criteria:

- A clearly demarcated non-spatter stain
- Without specific shape, but conforming to surface contours
- Absorbed or wicked into a permeable surface

Figure 3.31 When a volume accumulates on a permeable surface, it is absorbed into the surface producing a saturation stain. Saturation stains tend to mar other patterns. In this instance, pattern transfers on the back of the stabbing victim might have been of interest, but the saturation destroyed anything that may have been present.

Discussion:

Saturation stains occur as a function of blood accumulating on a permeable surface. Instead of forming a pool, the liquid blood is drawn into the surface. Saturations may be accompanied by clotting or overlying pools of blood, when the volume is greater than the surface can absorb. In some instances rather than absorbing downward with gravity, the liquid can be wicked upward into the target (e.g., clothing hanging down into a blood pool). See Figure 3.31.

Category: Flow

Family: Bloodstain — Non-Spatter — Regular Margin
Definition: The movement of liquid blood as a mass under the effect of gravity

Criteria:

- A clearly demarcated non-spatter stain
- Generally regular margins demonstrating movement along surface contours
- Margins lead from one point on a surface to another

Discussion:

Flows have clearly demarcated margins that lead from one point to another. They may be narrow or wide, straight or wavy. They may move across a surface freely or follow surface irregularities (e.g., along tile grout lines). See Figure 3.32.

Complex Patterns

The concept of the complex pattern is a necessary tool in the taxonomy. The idea presumes that because of the dynamic fashion in which stains are produced, some patterns will demonstrate characteristics of multiple categories. In some instances, even the basic pattern characteristics can intermix, making classification difficult. A complex pattern is one that incorporates characteristics of several categories. The problem for the taxonomy is that

Figure 3.32 A flow out of a blood pool on tile. Flows will follow any depression or surface irregularities they encounter.

complex patterns cannot be defined absolutely, other than to state it is a pattern with multiple characteristics. As there are many variations in which dynamic events associated with the scene can unfold, there are few limits to the variety of complex patterns. It is impossible then to simplify them into any hierarchy and assign a specific parent-child relationship.

An excellent example of a complex pattern is a hand dripping blood into the scene. It takes nothing more than movement and flicking of the wrist to turn the drip into a drip trail, and then into a cast-off pattern. However, the pattern itself will be one. Just the same, an initial application of a hand mark (a pattern transfer) can be followed by lateral movement that leaves evident smear characteristics. The complex pattern as a tool in the taxonomy allows the analyst to make defensible decisions and still account for the extremely dynamic conditions found in bloodstained scenes.

We hope, based on the foregoing taxonomy discussion, that it is clear we are not trying to complicate matters by interjecting a "new" classification system in bloodstain pattern analysis without purpose. We feel there is a definite purpose. If bloodstain pattern analysis is to become more objective, the most effective classification system is a taxonomy that defines specific observable criteria on which to make deductive classification decisions. In the end, we feel that all other systems of classification should ultimately be replaced by a taxonomic system. It is not that other systems are invalid; it is simply that the hierarchy of the taxonomy with its defined criteria and decision points provides the analyst with a more objective way (ergo more scientific) with which to reach conclusions.

Even if the reader rejects the taxonomy classification system and chooses to use any one of the prior classification systems, a natural by-product of the taxonomy provides a significant tool for any analyst; that is, a decision map.

Bloodstain Pattern Analysis Decision Map

You will recall the basic premise of bloodstain pattern analysis theory is that, based on stain size, shape, volume, orientation, and other physical characteristics, the analyst can

differentiate between basic types of bloodshed events. To support any claim about a pattern, the analyst must know and be able to articulate what characteristics led him to his decision. A bloodstain pattern analysis decision cannot be "because I said so." Experienced analysts easily describe most patterns (their associated characteristics) or appear to move through the decisions to arrive at a classification in what seems an intuitive fashion; however, it is anything but intuitive. It is a function of experience. If experience counts, that begs the question: What about the analyst without years of experience or, better yet, the analyst in training? How can we guide their classification efforts to assist them in making defensible objective decisions?

If we examine the taxonomy system closely, its very structure provides an underlying decision map for those making the analysis. Each level and branch of the taxonomy is a specific decision point the analyst must consider and resolve.

As pointed out, taxonomic-based classification systems find their roots in biology. They guide biologists in classifying plants and animals based on the presence or absence of some characteristic. Phillipe Esperança first suggested the decision map concept for bloodstain pattern analysis based on his training and experience in biology and, in particular, entomology.[7] His initial ideas and subsequent input to the authors significantly aided the development of the decision map given here. This decision map is a basic tool that will lead the analyst through a series of questions about the pattern in question. Each question asks about the presence or absence of a particular characteristic. By answering the questions in a proper order, the analyst is led to an objective result. Whatever the decision of the analyst, he can articulate what he observed that allowed him to make a classification decision.

Using the taxonomy structure, the resulting decision map is easily defined. Note that associations of classifications in the taxonomy hierarchy (Figure 3.7 and Figure 3.22) are indicated by both alphanumeric annotation and corresponding color to the decision map. For example, the category "Linear Spatter" in Figure 3.7 has the alphanumeric label of A.1. This label correlates to Group A.1 on the decision map (e.g., primary stains are elliptical/circular and they are arranged in a linear orientation).

Figure 3.33 shows that the initial decision point of the decision map is the same as the taxonomy: Are the droplets circular or elliptical (e.g., spatter)? This will guide the analyst to one of two major groups: Group A — patterns whose primary stains are circular or elliptical, or Group B — patterns whose primary stains are not circular or elliptical.

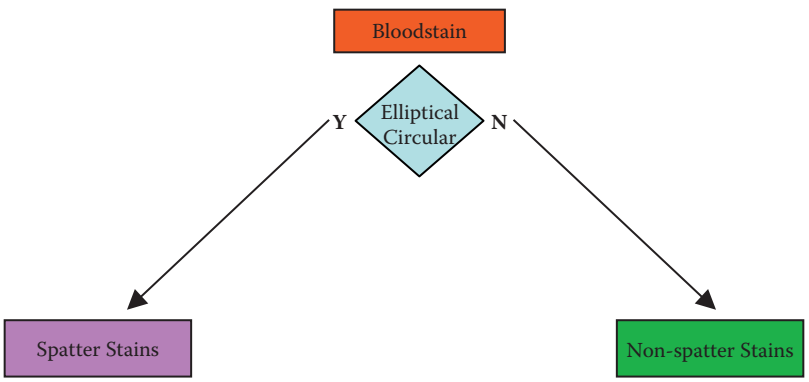

Figure 3.33 The decision map for bloodstain classification starts with the spatter/non-spatter issue. The question posed is: Are the stains elliptical or circular in shape?

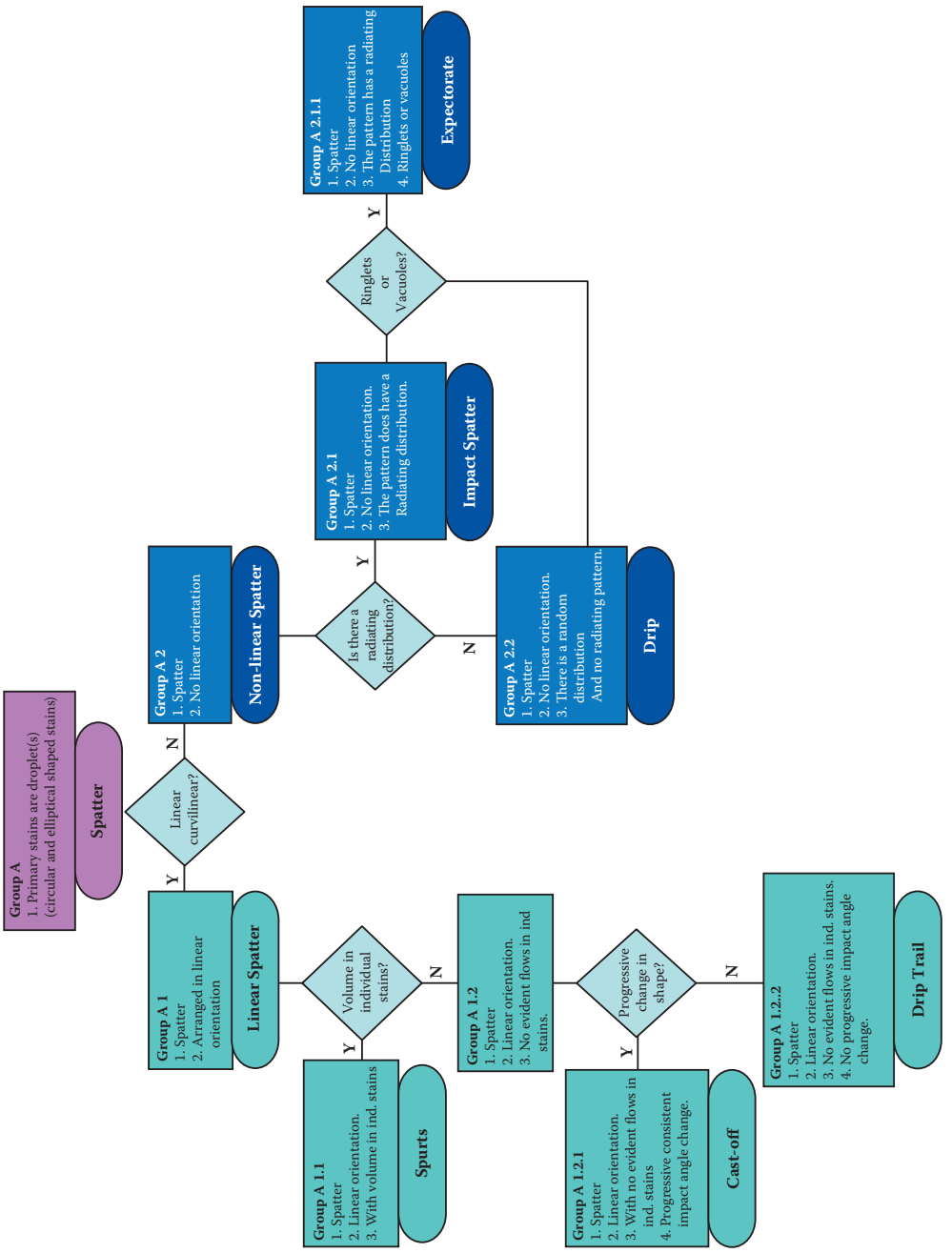

Figure 3.34 The decision map for the spatter-type stains.

Figure 3.35 Volume is evident in both the size of the stains and the flows coming from the individual stains. This points us to patterns produced by volume ejections.

Figure 3.34 graphically describes the decision process for the first group, those patterns where the primary stains are circular or elliptical. The questions posed are as follows:

Group A: Primary stains are circular or elliptical.

Q: Are the stains deposited in a linear or curvilinear orientation? (Refer to Figure 3.8.)
A: Yes. This leads to Group A.1 and the question:
Q: Is there evident volume in the individual stains or flows from the individual stains?
A: If yes, this leads to Group A.1.1, which is consistent with varying forms of blood ejected under pressure and volume (spurts). See Figure 3.35.
A: If no, this leads to Group A.1.2 and the question:
Q: Is there a progressive change in shape (changing impact angle) in the stains?
A: Yes. This leads to Group A.1.2.1, which is consistent with varying forms of *cast-off patterns*. See Figure 3.36.
A: No. This leads to Group A.1.2.2, which is consistent with varying forms of *drips trails*. See Figure 3.37.
A: There is no linear orientation (refer to Figure 3.15). This leads to Group A.2 and the question:
Q: Is there a radiating distribution present in the stains?
A: Yes. This leads to Group A.2.1, which is consistent with varying forms of *impact spatter* (see Figure 3.38), and the question:
Q: Are there ringlets or vacuoles present in the individual stains?
A: Yes. This leads to Group A.2.1.1, which is consistent with varying forms of *blood dispersed by air (expectorate)*. See Figure 3.39.
A: No, there is no radiating distribution. This leads to Group A.2.2, which is consistent with varying forms of *drips*. See Figure 3.40.

Figure 3.36 Note the shape of the individual stains change across the pattern. On the right, they are elliptical but they become more elliptical the further to the left you look. This change of shape in the stains combined with the linear deposit points us to patterns produced when blood is flung from an object.

Figure 3.37 In this pattern the shape of the stains changes but not in any regular fashion. Individual drops fall to the surface at varying angles, so there is no progressive change. This characteristic, combined with linear orientations, points us to drip trails.

Figure 3.38 The stains in this pattern show a radiating effect. This characteristic points us to patterns produced by varying forms of impact.

Figure 3.41 show the decision process for Group B, patterns where the primary stains are not circular or elliptical. The questions posed are as follows:

Group B: The primary stains are not circular or elliptical stains.

Q: Is there an irregular margin in the primary stains? See Figure 3.42.
A: If yes, this leads to Group B.1 and the following question.

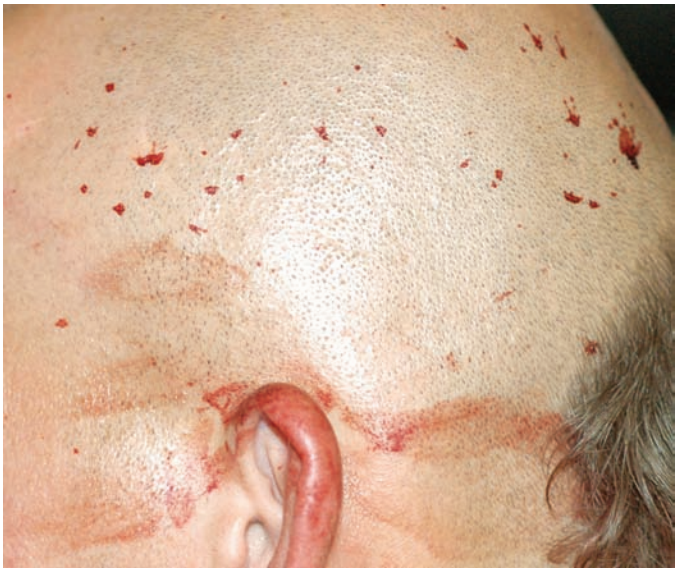

Figure 3.39 Several of the small spatters on this suspect have a small ringlet or vacuole present in the stain. He was in a fight with a man who had his throat cut. This characteristic points us to patterns produced by some form of air dispersion (e.g., expectorate).

Figure 3.40 A drip stain. These are large volume spatters deposited as a function of gravity.

Q: Are there numerous associated satellite stains or spines surrounding the margin?
A: Yes. This leads to Group B.1.1 and the following question:
Q: Are there randomly oriented spatters on the margin?
A: Yes. This leads to Group B.1.1.1, which is consistent with *blood into blood*. See Figure 3.43.
A: No. There are no randomly distributed spatters, but there are large spines and radiating spatter. This leads to Group B.1.1.2, which is consistent with *gushes* and *splashes*. See Figure 3.44.

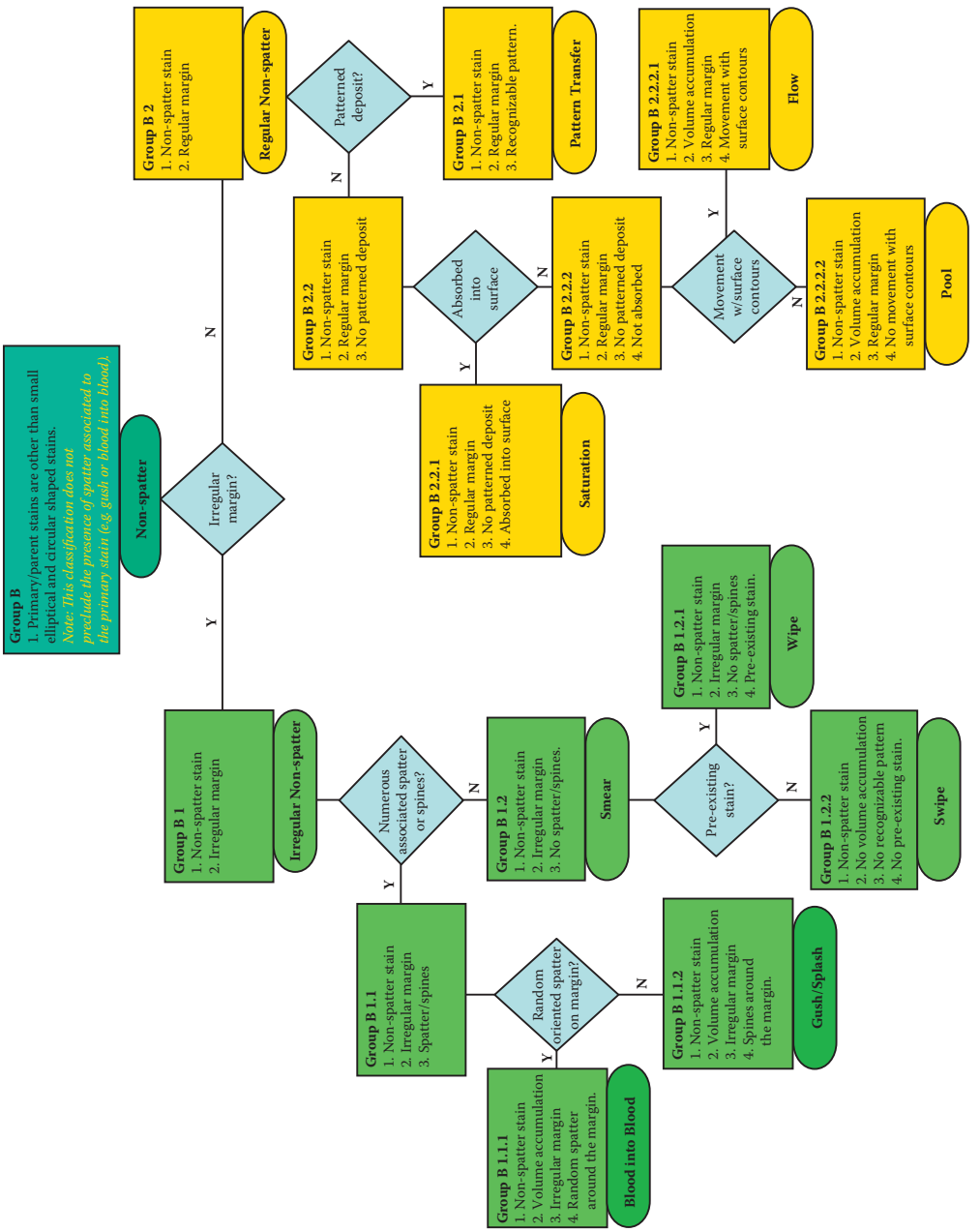

Figure 3.41 The decision map for the non-spatter (Group B) patterns.

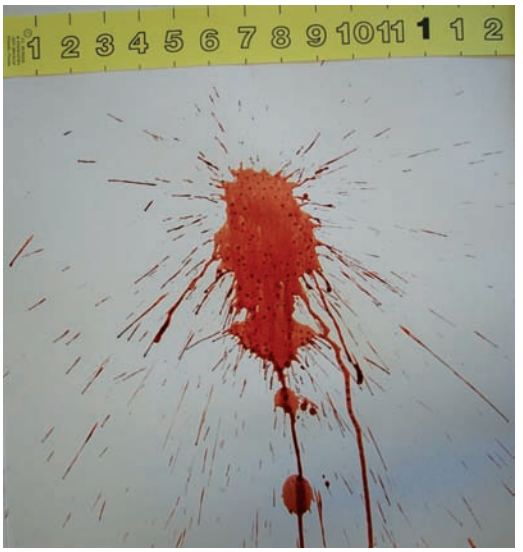

Figure 3.42 This pattern shows an irregular margin, with numerous spines and a shape that is distinct from the elliptical and circular shapes observed in individual spatter stains.

Figure 3.43 This pattern demonstrates an irregular shaped primary stain (e.g., overlapping drip stains) as well as secondary spatters that are randomly oriented around the primary stains. This characteristic is different from that observed in Figure 3.38.

Figure 3.44 This pattern has an irregular margin but none of the random spatter created by blood into another liquid. This characteristic is consistent with varying forms of blood ejected in volume and under pressure. (Photograph courtesy of David Stiles, Texarkana Police Department, Texarkana, AR.)

Figure 3.45 This pattern shows a clear pre-existing pattern that has been disturbed. This characteristic is consistent with varying forms of wipes.

Figure 3.46 This pattern shows deposition of blood with no evident pre-existing pattern. These characteristics are consistent with varying forms of swipe marks.

A: No, there are no associated spines or satellites. This leads to Group B.1.2, which is consistent with varying forms of *smears* and contact stains and the following question:

Q: Is there a pre-existing stain involved?

A: Yes. This leads to Group B.1.2.1, which is consistent with varying forms of *wipe patterns.* See Figure 3.45.

A: No pre-existing stain. This leads to Group B.1.2.2, which is consistent with varying forms of s*wipe patterns.* See Figure 3.46.

A: No irregular margins. This leads to Group B.2 and the following question:

Figure 3.47 A pattern showing patterned demarcations recognizable as a shoe mark. This characteristic is consistent with varying forms of pattern transfers.

Figure 3.48 The pillowcase has been exposed to a large volume of blood. In addition to producing spatter, a volume of blood soaked into the surface. This characteristic is consistent with varying forms of saturations.

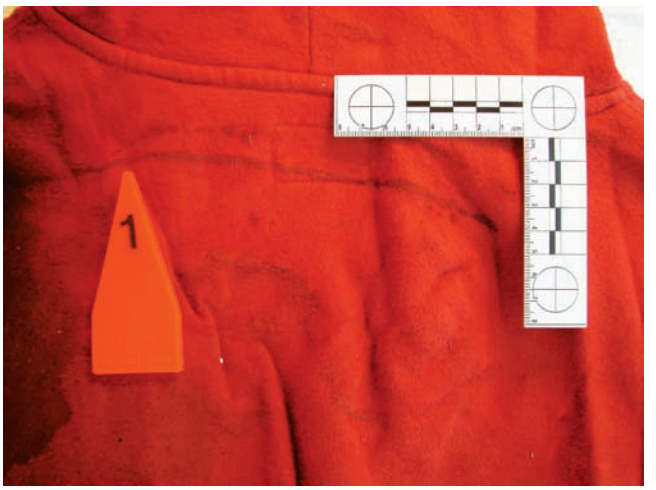

Figure 3.49 Pattern # 1 has regular margins that extend from the left side of the fabric across the back. This characteristic is consistent with varying forms of flows.

Q: Is there a patterned deposit in the stain?
A: Yes. This leads to Group B.2.1, which is consistent with varying forms of pattern transfers. See Figure 3.47
A: No, there is no patterned deposit. This leads to Group B.2.2 and the question:
Q: Is the blood absorbed or wicked into the surface?
A: Yes. This leads to Group B.2.2.1, which is consistent with varying forms of saturation. See Figure 3.48.
A: No. This leads to Group B.2.2.2 and the question:
Q: Is there evidence of blood movement along the surface contours?
A: Yes. This leads to Group B.2.2.2.1, which is consistent with varying forms of *flow patterns*. See Figure 3.49.
A: No movement. This leads to Group B.2.2.2.2, which is consistent with varying forms of *pools*. See Figure 3.50.

Figure 3.50 A blood pool resulting from significant flows from all three victims.

In action, the questions posed and the answers defined by the questioned pattern will lead the analyst to the basic pattern types no matter what classification system he or she chooses to use.

Altered Stains and the Decision Map

If the reader is experienced with other bloodstain classification systems, an obvious question might be: Why doesn't the taxonomy or decision map deal with the physically altered bloodstains (often referred to as PABS)?

PABS stains generally include stains that are clotted, dried, or diluted. These actions are typically the consequence of the stain's exposure to its environment, but do not define a singularly distinctive "pattern." Drying, dilution, and clotting can occur across any number of pattern types. For example, dilution can be found in various forms of spatter (e.g., expectorate patterns diluted by saliva or gunshot spatter diluted by cranial fluid) as well as non-spatter patterns (e.g., smears diluted by water). Alterations by dilution, clotting, and drying are simply adjectives that more fully describe other pattern types, and we have not included them as distinct patterns in the taxonomy itself. Altered stains are still important and are often of significance to the bloodstain pattern analyst; their value is discussed in detail in Chapter 10.

Practical Application of Taxonomy and Decision Map

In some respects, the taxonomy and resulting decision map may be confusing on an initial look, but their use is best understood by direct application. Consider the following two examples.

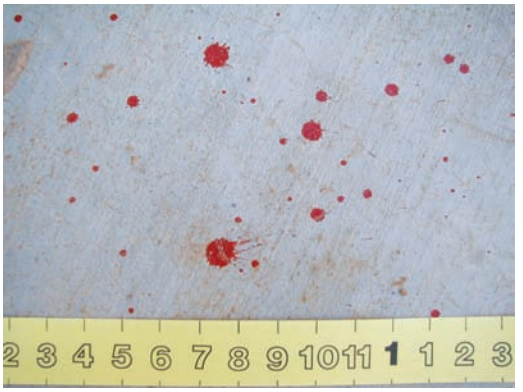

Figure 3.51 Taxonomy Example 1. Using the decision map, evaluate the stains in this picture. This evaluation should lead you to spatter, then to non-linear spatter.

Taxonomy Example 1

Examine Figure 3.51. Using the decision map, the first question is: Are the primary stains circular or elliptical? Yes, there is no question the primary stains are the result of droplets, with circular and elliptical shapes. This leads us to Group A.

Before proceeding, we have to be confident that we are not looking at multiple events. In other words, are we looking at related spatter stains? The figure shows a number of circular and elliptical shaped stains deposited on concrete. The size range of the stains is wide but consistent. The directional angles of the stains are all pointing left to right and slightly upward. If we examine the stain shapes, we see that all of the impact angles are consistent as well; we do not see significantly elliptical shapes to the left side of the circular shaped stains, nor do we see distinctly different directional angles (e.g., directional angles crossing each other). The presence of either might suggest two or more distinct events. Therefore, based on stain shape, size, and orientation we have what appears to be a series of related spatter stains.

The next question is: Are they arranged in a linear or curvilinear orientation? No, there is no evidence of a line of stains. The spatter is deposited across the target. This leads us to Group A.2.

The next question is: Is there a radiating dispersion? If we examine the directional angles of the stains, there is no evidence of a radiating effect. This precludes Group 2.1 (stains consistent with impact spatter) and leaves us at Group 2.2 (stains that are consistent with some form of passive drip).

Given these empirical characteristics, if the analyst considers them against Figure 3.7 (the graphic representation of the spatter taxonomy) once impact and expectorate are excluded for non-linear spatter, the only classification left is drip.

Now imagine for a moment that while examining the directional angles for the issue of a radiating dispersion, the analyst feels there is slight evidence of a radiating pattern, a minimal radiating effect. How does he or she classify the pattern? Rather than forcing the issue of whether there is a radiating effect, the analyst stops and classifies the pattern by its parent category, non-linear spatter (A-2). After evaluating the entire context of the scene, and having objectively excluded expectorate characteristics, the analyst might ultimately conclude the stains are not drips but rather some form of impact spatter. However, the classification does not force the issue. When using the decision map, if a decision point is reached and no decision is possible, then the analyst simply stops.

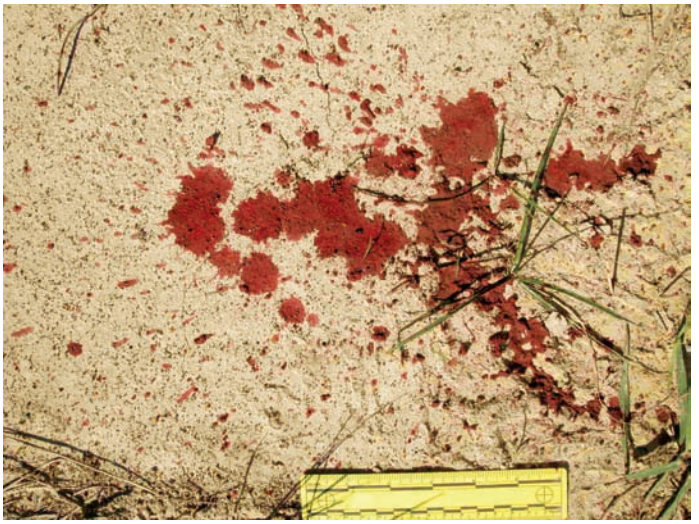

Figure 3.52 Taxonomy Example 2. Using the decision map, evaluate the stains in this picture. This evaluation should lead you to the non-spatter, irregular margin with no random oriented spatter.

Taxonomy Example 2

Examine Figure 3.52. Using the decision map, the first question is: Are the primary stains circular or elliptical? No. There is some indication of "spatter" but the primary stains are large and irregular shaped. This leads us to Group B.

The next question is: Do the stains have an irregular margin? The pattern is found on a rough surface, which impacts our evaluation, but if we look closely we will see that there are no regular contiguous margins in the stain. This leads us to Group B.1.

The next question is: Are there numerous spatters or spines associated with the primary stain? Yes, we can see protuberances from the primary stains and small stains all around the primary stains. This leads us to Group B 1.1.

The next question is: Are there randomly distributed satellite spatters around the pattern? This characteristic is again difficult to distinguish based on the rough surface. There are many satellites and they appear to radiate outward from the pattern; thus, they are not randomly distributed. However, given the surface, one analyst might opine differently from another. This is a difficult call. If the analyst is unsure, this leaves us at Group B.1.1.

If we consider the characteristics observed against the non-spatter taxonomy (see Figure 3.21), the classification would be an irregular margin stain. As smear and its children wipe and swipe were excluded, this leaves the categories gush/splash or blood into blood.

This general classification is valid, but will the scene context allow a refined conclusion? The analyst might consider the following issues:

Is there evidence of a drip trail leading up to this pattern in the scene?
A: There is none.
What types of injuries are present?
A: The victim has an incised wound to the heart.
Are there other patterns present on better surfaces?
A: Yes, a gush pattern is found on a dumpster near this pattern.

Blood into blood events are created by blood dripping down from an object. If this much volume is present, then such a drip did not appear out of the blue. If this is a blood into blood

event, we should expect drips either leading to or away from the pattern. There are none. On the other hand, a gush or splash is projected and will produce both spines and secondary spatter. There is evidence to suggest both. Lacking evidence of a drip and given an indication of spines, radiating secondary spatter, and the presence of an arterial wound as well as another gush pattern, the analyst would be justified in offering a *conclusion* that the stain is the result of a gush.

Applying the Decision Map with Other Bloodstain Pattern Classification Systems

Over the history of bloodstain pattern analysis, various groups have developed independent terminology to explain bloodstain pattern analysis. For example, the International Association for Identification (IAI) created a set of "standardized terms" in 1994, and two years later, the International Association of Bloodstain Pattern Analysts (IABPA) published a "suggested" set of terms as well. Since classification systems have developed in conjunction with these independent ideas on terminology, independent classification systems abound as well.

The authors choose not to make any value judgments regarding other classification systems or to claim that other systems are not valid. Of the various systems in use today, each provides a functional method of describing the basic pattern types. We certainly feel the taxonomic system is the future of bloodstain pattern analysis, but other systems are in use and will be for some time. Therefore, we will describe several classification systems and provide tables that should allow an analyst to use the decision map with these other systems of classification.

Figure 3.53 is an example of one of the tables provided. At the top, the table identifies to what system it applies, in this instance the "Passive, Spatter, Altered" system. The categories associated to the "Passive, Spatter, Altered" classification system are listed in the columns beneath it (boxed in red). In the far left column of the table the primary decision map categories are listed (highlighted in purple).

After the analyst uses the decision map and reaches a decision, he or she locates that group from the decision map on the table (see Figure 3.54). For the example, we will imagine the decision map led the analyst to the B 1.1.2 group. These patterns are consistent with various forms of gush and splash pattern. The analyst finds B 1.1.2 in the left-hand column and then follows that row across the columns to any boxes that are highlighted. In this instance, we find that the columns beneath the classifications Free Falling Volume and Projected Arterial Gush are highlighted. This indicates that the result of the decision map in this instance would best fit either of these classifications using the Passive, Spatter, Altered classification system.

The more recognized systems currently in use for bloodstain pattern analysis find their roots in the systems proposed by McDonell, Bevel and Gardner, Wonder, and James et al. These include the following.

Low, Medium, and High Velocity

The Low, Medium, and High Velocity system of classification is so engrained in bloodstain pattern analysis that it is nearly impossible not to encounter its use. Herb McDonell and Lorraine Bialousz originally suggested it in 1971. Initially published in *Flight Characteristics*

Classification System: Passive, Spatter, Altered							
Classification System Category	Contact	Flow	Pool	Saturation	Secondary Spatter (Blood into Blood)	Free Falling Volume (Splash)	Projected Arterial Gush
Decision Map Category							
B Non-spatter							
B.1 Irregular Margin							
B.1.1.1 Blood into Blood							
B.1.1.2 Gush/Splash							
B.1.2 Smear							
B.1.2.1 Wipe							
B.1.2.2 Swipe							
B.2 Regular Margin							
B.2.1 Pattern Transfer							
B.2.2.1 Saturation							
B.2.2.2 Flow							
B.2.2.2.2 Pool							

Figure 3.53 An example of the tables that will allow the analyst to use the decision map along with other classification systems. Each table will identify at the top the classification system to which it applies (bordered in red). Beneath this in the columns are the categories of stains identified by that classification system (highlighted in red). The groups from the decision map are listed in the far left column (highlighted in blue).

and Stain Patterns of Human Blood, MacDonell subsequently revised this document and published *Bloodstain Pattern Interpretation*. This system was continued in MacDonell's subsequent book *Bloodstain Patterns*, published in 1993. In effect, this classification system entails:

- Dripped and splashed blood — blood dripping into blood or blood ejected in volume without significant force
- Projected bloodstains — bloodstains ejected in volume under pressure, thus arterial
- Cast-off bloodstains — blood flung from objects in motion
- Medium velocity impact — bloodstains resulting from impacts in which the preponderant stain size was 1 mm or greater
- High velocity impact — bloodstains resulting from impacts in which the preponderant stain size was 1 mm or smaller
- Expirated bloodstains — bloodstains resulting from movement of air by a victim (e.g., breathing out, gasping)
- Transfer bloodstains — bloodstains transferred from one item to another[8]

Adopted and revised by both the IABPA and IAI, the resulting adaptations created the additional category of "Low Velocity." These subsequent alterations by a variety of authors resulted in adaptation of the size criteria for the "velocity" stains as follows:

Classification System: Passive, Spatter, Altered							
Classification System Category	Contact	Flow	Pool	Saturation	Secondary Spatter (Blood into Blood)	Free Falling Volume (Splash)	Projected Arterial Gush
Decision Map Category							
B Non-spatter							
B.1 Irregular Margin							
B.1.1.1 Blood into Blood							
B.1.1.2 Gush/Splash							
B.1.2 Smear							
B.1.2.1 Wipe							
B.1.2.2 Swipe							
B.2 Regular Margin							
B.2.1 Pattern Transfer							
B.2.2.1 Saturation							
B.2.2.2 Flow							
B.2.2.2.2 Pool							

Figure 3.54 For the example, using the decision map, the analyst arrived at the B.1.1.2 group. Locate this group in the far left column and then following the row across look for any highlighted categories. Those that are highlighted (e.g., Free Falling Volume and Projected Arterial Gush) are the classifications that best fit the result of the decision map.

- Low velocity (LVIS) — stains 4 mm or greater in diameter
- Medium velocity (MVIS) — stains 1 to 4 mm in diameter
- High velocity (HVIS) — stains 1 mm and under in diameter

There are problems with the LVIS, MVIS, HVIS system. The first concern is that spatter size of the various categories (e.g., low, medium, high) cross over one another. The size criterion is based on preponderant stain size, and MacDonell clearly indicated that spatter of larger or smaller size could be found in any of the patterns. Therefore, a certain amount of ambiguity always exists using this method. Perhaps the greatest detractor is the association of specific force levels to define what low, medium, or high velocity entails. LVIS was defined by MacDonell as 5 feet per second (fps) or less, while MVIS was defined as 5 to 25 fps and HVIS started at 100 fps.[9] This statement about the underlying force has resulted in associating MVIS to blunt trauma and HVIS to gunshot or explosive force to the exclusion of all other events. This too has created significant issues over the years.

Irrespective of these issues, if we apply the decision map to the LVIS, MVIS, HVIS system, the associations of basic pattern types to this system would appear as in Figure 3.55 and Figure 3.56.

Classification System: LVIS, MVIS, HVIS							
Classification System Category	LVIS	MVIS	HVIS	Castoff	Dripped	Projected	Expirated
Decision Map Category							
A Spatter							
A.1 Linear Spatter							
A.1.1 Spurts							
A.1.2.1 Cast-off							
A.1.2.2 Drip Trail							
A.2 Non-linear							
A.2.1 Impact							
A.2.1.1 Expectorate							
A.2.2 Drip							

Figure 3.55 Applying the spatter decision map to the LVIS, MVIS, HVIS classification system.

Classification System: LVIS, MVIS, HVIS				
Classification System Category	Transfer	Splashed	Projected	Dripped
Decision Map Category				
B Non-spatter				
B.1 Irregular Margin				
B1.1.1 Blood into Blood				
B.1.1.2 Gush/Splash				
B.1.2 Smear				
B.1.2.1 Wipe				
B.1.2.2 Swipe				
B.2 Regular Margin				
B.2.1 Pattern Transfer				
B.2.2.1 Saturation				
B.2.2.2 Flow				
B.2.2.2.2 Pool				

Pools, Flows and Saturations are not listed as specific categories in this system

Figure 3.56 The non-spatter decision map application to LVIS, MVIS, and HVIS.

Spatter, Non-Spatter

In 2001, Anita Wonder set forth a classification system using two primary groups, with the recognition of a third group known as composites. Wonder based her primary groups on the most evident physical difference found across all different types of stains, that is, are the stains/pattern made up of spatter or some other type of staining? As described in the decision map, spatter is easily recognized because blood that has been put in flight by any mechanism ultimately appears as either round or elliptical stains. Size of the stains may vary, but the shape is a constant; thus, Wonder set a very functional foundation for her system. Unfortunately, it broke down from there by trying to force a mechanistic source (e.g., blunt force vs. gunshot) into the classifications using more ambiguous criteria. Wonder's classification system entailed:

- Spatter Groups
  - Impact Spatter
    - Blunt force
    - Gunshot
    - Exhalation
    - Splash
  - Cast-offs
    - Drip
    - Swing
    - Cessation
  - Arterial
    - Gush
    - Spurt
    - Rain
- Non-Spatter Groups
  - Transfer
    - Blockage
    - Simple Direct
    - Moving
      - Wipe
      - Swipe
  - PABs (Physically Altered Bloodstains)
    - Dry
    - Clot
    - Mix
  - Volume[10]

Another innovation by Wonder was the composite group, which was considered to be complex patterns involving aspects of both the spatter and non-spatter groups. Wonder's intent and specific classifications for this group were anything but clear, but she was the first to articulate in writing that the analyst should expect and be prepared to deal with the idea of a complex pattern created by dynamic circumstances.

Applying the decision map to Wonder's version of Spatter/Non-Spatter, the associations of basic pattern types to this system would appear as in Figure 3.57 and Figure 3.58.

Classification System: Spatter, Non-spatter								
Classification System Category	Impact Blunt	Impact Gunshot	Impact Exhalation	Castoff Swing	Castoff Drip	Castoff Cessation	Arterial Spurt	Arterial Rain
Decision Map Category								
A Spatter								
A.1 Linear Spatter								
A.1.1 Spurts								
A.1.2.1 Cast-off								
A.1.2.2 Drip Trail								
A.2 Non-linear								
A.2.1 Impact								
A.2.1.1 Expectorate								
A.2..2 Drip								

Figure 3.57 Applying the spatter side of the decision map to Wonder's classification system.

Classification System: Spatter, Non-spatter							
Classification System Category	Transfer Blockage (Void)	Transfer Simple	Transfer Moving Swipe	Transfer Moving Wipe	Volume	Impact Splash	Arterial Gush
Decision Map Category							
B Non-spatter							
B.1 Irregular Margin							
B.1.1.1 Blood into Blood							
B.1.1.2 Gush/Splash							
B.1.2 Smear							
B.1.2.1 Wipe							
B.1.2.2 Swipe							
B.2 Regular Margin							
B.2.1 Pattern Transfer							
B.2.2.1 Saturation							
B.2.2.2 Flow							
B.2.2.2.2 Pool							

Figure 3.58 Applying the non-spatter decision map to Wonder's classification system.

Passive, Spatter, Altered

In 2005, James et al. published *Principles of Bloodstain Pattern Analysis, Theory and Practice* (Authors' note: This book should not be confused with *Bloodstain Pattern Analysis Theory and Practice*, *A Laboratory Manual*, first published in 1990 by the authors). In their book, James et al. set forth a classification system with three primary categories. These included:

1. Passive/gravity
   - Contact
   - Drops
   - Flow
   - Saturation/pooling
   - Free falling volume
2. Spatter
   - Impact mechanism
   - Secondary mechanism (e.g., satellites, wave cast-off)
   - Projection mechanism
3. Altered
   - Clotted
   - Diluted
   - Dried
   - Diffused
   - Insects
   - Sequenced
   - Voids[11]

Although touted as "taxonomic," this system did little to refine the idea of using more defined criteria, or at least it failed to articulate those criteria.

Applying the decision map to the Passive, Spatter, Altered system, the associations of basic pattern types to this system would appear as in Figure 3.59 and Figure 3.60.

Passive, Transfer, Projected/Dynamic

In 2002, the authors published a classification system in the second edition of this book. It incorporated four primary categories. This system was, of course, mechanistic in nature. The categories and their major subcategories included:

- Passive
  - Clot
  - Drip
  - Flow
  - Pool
  - Saturation
- Transfer
  - Pattern transfer
  - Swipe
  - Wipe

Classification System: Passive, Spatter, Altered							
Classification System Category	Impact Gunshot	Impact Beating	Impact Industrial	Passive Drop(s)	Projected Castoff	Projected Expiratory	Projected Arterial Spurt
Decision Map Category							
A Spatter							
A.1 Linear Spatter							
A.1.1 Spurts							
A.1.2.1 Cast-off							
A.1.2.2 Drip Trail							
A.2 Non-linear							
A.2.1 Impact							
A.2.1.1 Expectorate							
A.2..2 Drip							

Figure 3.59 Applying the decision map to the James et al. Passive, Spatter, Altered classification system on the spatter side.

Classification System: Passive, Spatter, Altered							
Classification System Category	Contact	Flow	Pool	Saturation	Secondary Spatter (Blood into Blood)	Free Falling Volume (Splash)	Projected Arterial Gush
Decision Map Category							
B Non-spatter							
B.1 Irregular Margin							
B.1.1.1 Blood into Blood							
B.1.1.2 Gush/Splash							
B.1.2 Smear							
B.1.2.1 Wipe							
B.1.2.2 Swipe							
B.2 Regular Margin							
B.2.1 Pattern Transfer							
B.2.2.1 Saturation							
B.2.2.2 Flow							
B.2.2.2.2 Pool							

Figure 3.60 Applying the decision map to the James et al. Passive, Spatter, Altered classification system on the non-spatter side.

Classification System: Passive, Dynamic						
Classification System Category	Impact	Passive Drops	Expiratory	Castoff	Arterial Spurt	Drip (Trail)
Decision Map Category						
A Spatter						
A.1 Linear Spatter						
A.1.1 Spurts						
A.1.2.1 Cast-off						
A.1.2.2 Drip Trail						
A.2 Non-linear						
A.2.1 Impact						
A.2.2 Expectorate						
A.2..2 Drip						

Figure 3.61 The decision map can also be utilized with the authors' Passive/Dynamic system detailed in the second edition of this book. Here are the associations on the spatter side of the decision map.

- Projected (also referred to by many as dynamic)
  - Arterial
  - Cast-off
  - Spatter
  - Expectorate
  - Splash
- Miscellaneous
  - Fly spot
  - Void
  - Skeletonized
  - Capillary[12]

This system included all of the primary pattern types, as well as some peculiar patterns (e.g., fly spots); but like other systems, it did not clearly articulate what criteria define a particular pattern. Although we now believe a taxonomic system is the most effective classification system (as it is non-mechanistic), this particular system was and is functional.

Applying the decision map to the Passive/Dynamic system, the associations of basic pattern types to this system would appear as in Figure 3.61 and Figure 3.62.

Summary

There are multiple methods of classifying bloodstain patterns. The most effective method is a taxonomic classification system used along with a decision map. Such a system includes

Classification System: Passive, Dynamic								
Classification System Category	Pattern Transfer	Wipe	Swipe	Flow	Blood into Blood	Pool	Saturation	Arterial Gush
Decision Map Category								
B Non-spatter								
B.1 Irregular Margin								
B.1.1.1 Blood into Blood								
B.1.1.2 Gush/Splash								
B.1.2 Smear								
B.1.2.1 Wipe								
B.1.2.2 Swipe								
B.2 Regular Margin								
B.2.1 Pattern Transfer								
B.2.2.1 Saturation								
B.2.2.2 Flow								
B.2.2.2.2 Pool								

Figure 3.62 The decision map can also be utilized with the authors' Passive/Dynamic system detailed in the second edition of this book. Here are the associations on the non-spatter side of the decision map.

both written criteria (specific physical characteristics) that must be present to include the pattern in a category, as well as asking questions about the characteristics in a regular and methodical order.

Recognizing that not everyone follows a single classification system, the decision map detailed in this chapter can still be used effectively on any current classification system. The reason for this is that all systems (no matter what their initial perspective may be) ultimately refine themselves down to the basic reproducible bloodstain pattern types. No matter how one names these basic pattern types, they will include:

- Blood dispersed from a source by a force (e.g., impact patterns, expectorate)
- Blood ejected over time from an object in motion (e.g., cast-off patterns)
- Blood ejected in volume under pressure (e.g., spurt and gush patterns)
- Blood dispersed through the air as a function of gravity (e.g., drip patterns, drip trails)
- Blood that accumulates and/or flows on a surface (e.g., pools and flows)
- Blood that is deposited through transfer (e.g., smears and pattern transfers)

The most important aspect of classification is that in order to classify something into a category, the analyst must be able to point to the requisite characteristics. This prevents untrained individuals from stepping in front of a court and making claims that cannot be supported. Before one can claim a classification, the analyst must be able to say, "Here

in the stain we see criteria 1, here we see criteria 2." As we have said before, bloodstain patterns are graphic evidence; the analyst can always show and tell how he arrived at a classification. Classification decisions presented as "because I said so" mean nothing and are simply supposition.

Classification, however, is but one step in the overall analysis. Classification sets the stage for the analyst to more effectively define a source event for any given stain. Classification considers the stain and only the stain (the physical characteristics), while any opinion as to the source of the stain will encompass issues such as scene context and interrelationships to other patterns or evidence. Thus, an ambiguous stain or pattern might only be classified in a general sense (e.g., as non-linear spatter), but ultimately be evaluated by a knowledgeable analyst who can offer a valid, more refined conclusion as to the source event. This distinction between the step of classification and the presentation of an ultimate opinion is important. They are interrelated, but they are not one and the same.

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A Methodology for Bloodstain Pattern Analysis

4

In an environment where lawyers routinely attack the tenets of every modern forensic discipline, it is imperative that practitioners of any forensic discipline know and apply a functional methodology. Across any discipline there may be no single "absolute" method; in fact, different functional and valid methods may exist. Although these methodologies may vary in minor ways, they will all follow a predictable path, that of scientific method. Their existence and application enhance the probability that the analyst, no matter what level of expertise, will arrive at a defensible conclusion.

In the past, the discipline of bloodstain pattern analysis has suffered needlessly in terms of reputation within the legal system. In many ways, bloodstain pattern analysts have been their own worst enemy. Examples include the failure to articulate a defined taxonomy for bloodstain classification, and the fact that too often students leave a basic technical course reciting only three phrases — low, medium, and high velocity — and then fail to understand fully the application of these classifications. Worse yet, individuals claiming themselves experts in the area of bloodstain pattern analysis have literally stated the discipline is an art and subjective.[1]

How is it possible that a discipline with a 150-year consistent history can be labeled an "art" and suffer from such misconceptions? The answer in large part is attributed to not fully understanding or applying an accepted methodology. Analysts are taught all of the skills applied in bloodstain pattern analysis — recognition of patterns, impact angle determination, point of convergence, area of origin determinations — but not everyone leaves a technical course understanding how and in what order to apply these skills. Thus, the inability of analysts to explain how the "analysis" was performed leaves the perception that the discipline is without foundation. If the rank and file analyst can't explain in simple terms how they go about the analysis, then how can the discipline hope to escape a tag of "unscientific"? The problem, however, has never been the lack of appropriate procedures, but rather a failure to articulate these procedures.

As a discipline, bloodstain pattern analysis defines conclusions specific to the events that occurred during the bloodshed incident by using information derived from size, dispersion, shape, volume, pattern characteristics, the number of bloodstains, and their relationship to each other and the surrounding scene. This is done by asking and answering questions using scientific method.

Scientific Method

Often in attacking an analysis, opposing experts and lawyers imply that only the "scientist" can apply scientific method; mere mortals such as analysts, investigators, and police are incapable of understanding the mysterious tenets of this thing called "scientific method." In such arguments, one can be sure that the counselor will use great emphasis and intonation each time he uses the word "science." More often than not, these same individuals will have no clue of what scientific method is or exactly what it entails. Nevertheless, by furthering

the myth that scientific method is something mysterious and beyond the average human's understanding, they hope to prevent the presentation of critical information. So what is "scientific method" and how does it relate to the process of crime scene reconstruction and bloodstain pattern analysis?

First and foremost, scientific method is not some mysterious, complex, or magical thing. It is, in its simplicity, a defined process used to resolve complex problems. Scientific method might best be described as a circular path that begins with a question, which leads to an answer, which begets another question. In effect, any research effort using scientific method creates an ever-expanding and self-correcting body of knowledge related to some specific issue.

What scientific method is not, however, is the mere collection or regrouping of information. Having the information in front of you and not recognizing what it means is a classic failure of many in the criminal justice system. As we will discover, it is the analysis of the data collected through scientific method that leads to knowledge. Mere ownership of information means nothing.

Scientific method is certainly not some distant concept for the elite, unattainable by the non-scientist. It is imperative to dispel this particular idea, as it paints any individual employed as a "non-scientist" as inferior and incapable of achieving a valid conclusion. As Leedy commented in his book *Practical Research, Planning and Design:*

> Everywhere our knowledge is incomplete and problems are awaiting to be solved. We address the void in our knowledge, and those unresolved problems, by asking relevant questions and seeking answers to them. The role of research [also known as scientific method] is to provide a method for obtaining those answers. By inquiringly studying the facts, within the parameters of the scientific method. … [But] the word "research" has a certain mystique about it. It suggests to many people an activity that is exclusive and remote from everyday life…. Although this concept of research may seem somewhat remote or academic, many of us rely on a truncated form of it each day to dispose of less formal matters than those solved by the more elaborate methodology of pure research.[2]

Thomas Huxley, a nineteenth century student of science wrote in this regard:

> The method of scientific investigation is nothing but the expression of the necessary mode of working the human mind. It is simply the mode by which all phenomena are reasoned about, rendered precise and exact. There is no more difference, but just the same kind of difference, between the mental operations of a man of science and those of an ordinary person. As there is between a baker or butcher weighing out his goods in common scales and the operations of a chemist in performing a difficult and complex analysis.[3]

Henry Rhodes, who clearly believed in scientific methods for criminal investigation, stated that it is a fallacy to suggest that the academically trained are more likely from start to finish to be able to handle a criminal investigation than are the police. Trained observation, discrimination, and a sense of the value of evidence are necessary skills that police experience provides.[4]

Pirsig described an insightful correlation of the day-to-day use of scientific method in his book, *Zen and the Art of Motorcycle Maintenance*. This odd tale of self-discovery devotes an entire chapter to explaining scientific method. Pirsig, in describing a mechanic's dilemma of identifying the source of a mechanical problem, wrote:

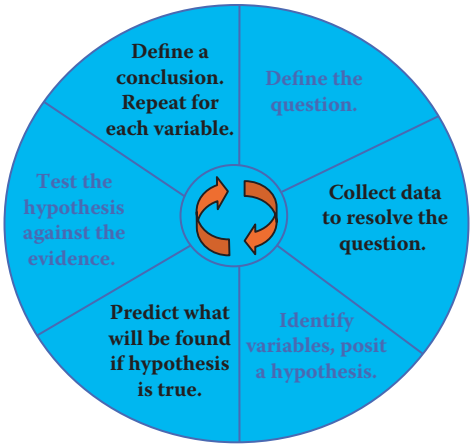

Figure 4.1 Scientific method is a structured process of asking and resolving distinct questions using several steps. Various authors describe these steps in slightly different fashions, but all follow a similar path. The answer to one question often begs another question, thus the process is circular. The result of scientific method is an ever-expanding, self-correcting body of knowledge.

> [The] solution of problems too complicated for common sense to solve is achieved by long strings of mixed inductive and deductive inferences, that weave back and forth between the observed machine and the mental hierarchy of the machine found in the manuals. The correct program for this interweaving is formalized scientific method.[5]

Pirsig's interesting association is quite accurate. We humans tend to resolve problems using an odd mixture of empirical observation combined with rationalism in order to make sense of complex or abstract ideas. This mixture is itself the very nature of scientific method, which seeks to blend empirical knowledge (that gained through observation and deduction) with rationalism (that gained through application of reasoning and inductive thought). However, scientific method provides structure to the process. Different authors describe scientific method differently, but this structure includes six basic steps (see Figure 4.1).

The first step in scientific method is to identify the problem. This ensures that a focus is established and all efforts are directed toward the intended goal. The most significant part of defining a problem is in breaking a larger problem down into smaller sub-problems. As we introduce the crime scene analysis concept of "Event Analysis" later in this book, the importance of dealing with discrete, small problems will become quite evident. However, it is just as important in bloodstain pattern analysis.

Consider this step in relation to a simple bloodstain pattern. If your stated problem is "What does this stain establish?" the problem is far too broad to begin with. Smaller, more discrete, issues must be answered before the larger problem is resolved. These include:

- Is the stain actually blood?
- If it is a bloodstain, where in the established classification of bloodstain pattern analysis does it fit?
- Given the classification, what mechanisms were present in the scene to create the stain?
- Is one mechanism more probable than another is, and if so why?

In order to resolve the larger question of "What does this bloodstain establish?" one must first deal with and answer the smaller questions.

The second step of scientific method is to collect and gather data that might help establish an answer to the question. In pure research and certainly in physical science, this step entails the laymen's icon of scientific method; that is, the scientist performing an experiment. However, data is collected through means other than experimentation alone. In the instance of crime scene or bloodstain pattern analysis, empirical evidence is present in the scene photos, scientific reports, and other information collected during the investigation. Occasionally it may be necessary for the crime scene or bloodstain pattern analyst to design and conduct an "experiment" to help aid in the discovery process. Unfortunately, creating objective experiments is an area where great care should be taken to design the experiment properly. In Chapter 16, we discuss issues involved with designing and conducting such experimentation. As previously mentioned, having the data and understanding the data are two entirely different things. In this step, the analyst must also look for and recognize interrelationships of the data.

The third step of scientific method is to posit some hypothesis regarding the problem. What might the solution be? A hypothesis is an educated guess and vastly different from a mere guess. The hypothesis assists the analyst in recognizing where data may or may not be found.

The fourth step is to make predictions relative to the hypothesis. If the hypothesis were true, what would one expect to be present in the scene or the data available? If the hypothesis were false, what predictions could be made? Predictions are nothing more than simple "if this, then that" statements. Such predictions will also point the analyst to data he might otherwise have missed.

The fifth step is to test the hypothesis by comparing our expectations (predictions) for a given hypothesis against the observed data. If correct, a hypothesis will demand that certain things occurred, and therefore evidence of these occurrences will exist. If we put forth a hypothesis that a given bloodstain was created by a specific mechanism, then somewhere in the data we should find evidence supporting the availability and presence of this mechanism in the scene. Furthermore, we may be able to create a similar mechanism and, with its employment, create a similar type stain. It is important to recognize that in terms of finding answers to problems, scientific method is far more effective for disproving a given hypothesis than it is for proving a single hypothesis. Often referred to as premise negation, scientific method will allow us to state with some level of authority that certain things could not occur, but it will not always allow us to identify exactly what did occur.

After testing a given hypothesis, the analyst is left with one of three possibilities. The hypothesis is supported by the data indicating it is possible, the hypothesis is rejected and excluded as a possibility, or the data is inconclusive. If rejected, the hypothesis must be altered or an alternative hypothesis considered. Remember that in scientific method, the data defines the conclusion; the conclusion does not define the data. This important nuance is lost on any number of professionals, scientific background or not, and manifests itself in behavior where individuals begin to rationalize why certain items of evidence or data are unimportant or "don't matter."

The final step in the scientific method is to conclude something from the information examined. What one concludes is dependent upon the data and interrelationships. After exhaustive study, we may conclude that we cannot answer the question. On the opposite end of the spectrum, we may conclude that we have a clear answer to a given problem.

One never really knows until after the analysis. This is perhaps one of the more important aspects of applying scientific method — recognizing what we do not know. As Aristotle once commented while comparing himself to an antagonist, "I am better off than he is, for he knows nothing, but thinks he knows, while I neither know, nor think I know. In this latter particular I seem to have slightly the advantage of him."[6] The analyst must always remain cognizant of what he does not know.

The greatest misunderstanding of science and scientific method lies in the conclusion. One of the greatest myths of science is that "scientific certainty" defines something absolutely, that science provides unwavering answers. This simply is not the case. To understand this issue better, we must elaborate on science and its role. Science seeks to explain our world; it does so by seeking theories that explain observed phenomena. As Jon Nordby stated, "The goal of scientific explanation since the time of Galileo has been to expose nature's general covering laws."[7] Stephen Hawkins's also commented on this aspect in relation to the science of cosmology, stating, "The eventual goal of science is to provide a single theory that describes the whole universe."[8] But Hawkins went on to explain that the basic theories by which science understands our universe are in fact inconsistent with each other. And if inconsistent, then one must be wrong in some aspect. Science knows and understands this, but accepts the theories as the best explanation possible at the moment, while seeking a combined theory that will ultimately incorporate them all but eliminate the inconsistencies.

Science gives definitive answers but not ultimate truths. Leedy described this idea in depth, defining what he called regions of data. The first region was primary data, which lies closest to truth. Leedy felt primary data is "the most illuminating, the most truth manifesting," while secondary data although helpful, lies further from the realm of truth. In cautioning the research student to be wise enough to know that what one makes from the data is truly only a glimpse of ultimate truth, Leedy stated:

> The English word for fact comes from the Latin. The Latin origin is in the word facere, meaning "to make" — what the situation makes or manifests to the observer. The entomology provides the first clue as to the nature of data, they are manifestations of the truth rather than the truth itself. No one has ever looked upon the truth itself — pure, undisguised, naked truth. …The mind yearns to understand the Ultimate. As a means to that goal, we have chosen the pathway of research [scientific method]. But it always ends at the farthest reaches of data, which are at the brink of a canyon in whose depths lies the inaccessible Ultimate Truth. … Truth is forever just beyond what is represented by the data and hence, just beyond human grasp.[9]

Scientific method provides us with an understanding, a recognition of what the data represents. At times, the data may be very precise, providing clear and specific information in some area of an analysis, but more often, it will allow us only a glimpse of what happened. Just as physicists accept that the theories of relativity and quantum mechanics are the best understanding of our world given our current knowledge and technology, we must accept that a conclusion derived from scientific method brings us only to the best explanation given the data.

But does applying scientific method to an investigation elevate the investigative process to the status of "science"? Perhaps Nordby answers this best, referring again to science's goal of discovering covering laws. He commented that science starts with a phenomena and works backward toward a covering law. Once established, such laws help predict and explain other phenomena. However, there are no covering laws that define acts such as

murder. Crime lies at an intersection of many laws and causes. In such instances, explanations come first and they are derived by reasoning backward. Nordby then writes:

> Reasoning backwards analytically requires reading natural signs, formulating tentative explanations, and methodically testing them. … These explanations do not become "less scientific" because they fail to invoke established laws of nature, or "more scientific" because they appeal to covering laws. The "scientific" status of an explanation is independent of its connection with the laws of nature.[10]

Scientific method seeks to answer questions using a standard process. At its core, scientific method relies on an ability to define discrete objective questions, seek and find answers to those questions, and ultimately apply the answers in order to solve larger, more complex questions. If posing and answering questions is the heart of scientific method, then that begs the question what does the bloodstain pattern analyst ask? The ultimate question in bloodstain pattern analysis is: How was this stain or pattern created? To achieve an answer to that, the analyst first asks and answers a number of far more discrete questions.

A Practical Methodology for Applying Scientific Method

If the bloodstain pattern analyst does not know what questions to ask and in what order to ask them, how then can he functionally apply scientific method? A practical approach that solves this problem can be articulated in an eight-step methodology. The bloodstain pattern analyst should:

1. Become familiar with the entire scene.
2. Identify the discrete patterns among the many bloodstained surfaces.
3. Categorize these patterns based on an established taxonomy.
4. Evaluate aspects of directionality and motion for the pattern.
5. Evaluate angles of impact, points of convergence, and areas of origin.
6. Evaluate interrelationships among patterns and other evidence.
7. Evaluate viable source events to explain the pattern, based on all of the evidence.[11]
8. Define a best explanation of the events.

These eight steps effectively solve "how" scientific method is applied in bloodstain pattern analysis.

Step 1: Become Familiar with the Entire Scene

No scene analysis is ever attempted without first assessing the limits of the scene and knowing generally what is contained within it. This step involves answering the most basic questions posed in crime scene processing: What is the true extent of this scene? What areas will I consider and what items are present? If the analyst inappropriately limits himself or herself, critical stains and/or evidence may be overlooked.

To preclude this, before any other action, the bloodstain pattern analyst seeks to familiarize himself with the scene using whatever means and data are available. This includes seeking out information relevant to post-incident artifacts. It is a rare situation when EMS

Figure 4.2 An overall of one room in a homicide scene. In the initial step of assessing the scene, the analyst looks at what is present, considers issues of what is and is not evidence, and what may be post-incident artifacts. Note the clothing in the lower right corner; it appears cut off. On this initial look, it appears to be a post-incident artifact created by Emergency Medical Services (EMS).

and police activity fail to disturb the scene in some fashion. Whenever possible, the analyst should seek out initial responding officers and any initial documentation (e.g., photos exposed by initial responders) to compare it to the condition of the scene as viewed by the analyst.

Figure 4.3 Another view of the room and artifacts present.

Figure 4.4 A better view of the bed. Bloodstains of various types as well as wall defects are evident.

Case Example: Become Familiar with the Scene

Figure 4.2, Figure 4.3, and Figure 4.4 depict one room in a major crime scene. The overall scene consists of a home in which three victims were beaten in three different rooms. To illustrate methodology, the example will consider a single room.

The room depicted is a sparsely furnished bedroom. The victim found in this room showed signs of life and was removed by EMS. She subsequently died as a result of multiple blunt force injuries. In surveying the room from the entryway at the northeast corner, we observe multiple bloodstained surfaces in the northeast quadrant, including the floor. The victim was removed from a position behind the doorway and luckily a photograph that shows her position was taken by an initial responding officer (see Figure 4.5). This photograph shows that many of the stains we observe on the floor, as well as the bloodied clothing, are actually post-incident artifacts created as EMS worked with the victim. By comparing Figure 4.5 with Figure 4.2, it is evident that the white print comforter has been repositioned in the room, which may explain the lack of bloodstains farther to the west. This is critical information, which will aid us in the next step of the process.

Figure 4.5 This photo taken by initial responding officers before the victim was removed is significant. In it, we can contrast the condition of the clothing, the floor, and the position of the white comforter in comparison to the way it was found and documented by the crime scene team (see Figure 4.2, Figure 4.3, and Figure 4.4).

Step 2: Identify Discrete Patterns

Bloodshed situations often involve multiple events that are ongoing in an area. Because of these events, stains and patterns can be deposited on top of or around other stains. These patterns tend to merge, making it difficult, if not impossible, to distinguish between them. In this step, the analyst answers these simple, but often elusive, questions: Where are the patterns I intend to evaluate? Which of these stains belong together?

How does the analyst make this assessment? A critical consideration is the stain's size, shape, position, and directionality. A group of similar sized elliptical stains that appear to radiate out from a central point, and a series of linearly positioned circular stains with consistent directionality help the analyst determine initially what stains he believes entail a particular "pattern." Note that it is almost impossible to separate aspects of Step 3 from this consideration, but any initial classifications are exactly that, an initial hypothesis. Over time, these beliefs may or may not hold up. Stains the analyst thought were related may prove to be two or more patterns overlying each other. Patterns that appeared to be one thing might actually turn out to be another. These initial beliefs are simply initial assessments that focus and guide the examiner in the subsequent steps of the analysis.

Figure 4.6 A close-up of Stain Group 3, which consists of a large number of small circular and elliptical shaped stains on the wall. Their size, shape, dispersion, and directionality suggest they are associated to one another, yet we readily recognize they may be from multiple similar events.

Figure 4.7 A close-up of Stain Group 4. All around this group are small circular and elliptical stains associated with Group 3, but the pattern of concern is the staining in and around the defect.

Case Example: Identify Discreet Patterns

For purposes of the example, the concentration will be on the primary stains, ignoring many of the smaller stain groups. Looking at Figure 4.2 through Figure 4.5 allows us to eliminate a number of the contact stains observed in the final scene. As these are post-incident, they serve no value to the analysis.

In Figure 4.2, there is a large stained area on both the vertical and horizontal aspects of the box spring. Beneath this area is a large blood pool just in front of the brown slipper. This is Group 1, an area for consideration.

In Figure 4.3, excluding the numerous post-incident contact stains between the door and the bed, there is a large stained area at a point consistent with the victim's final resting position. This is Group 2.

In Figure 4.4, there are a large number of very small circular and elliptical shaped stains evident on the wall above the mattress. This is Group 3 (see Figure 4.6).

To the right of these stains are additional stains surrounding what appear to be physical defects in the wall (see Figure 4.7). This is Group 4.

When the pillow from the floor that is leaning against the east wall is removed, we find an additional pattern present on the wall as well as similar staining on the back side of the pillow. See Figure 4.8 and Figure 4.9. This is Group 5.

On the top surface of the pillow present on the bed is a large stained area (see Figure 4.10). This is Group 6.

Above Group 4 and to the right of Group 3 is another grouping of larger stains. This is Group 7. See Figure 4.11.

There are now seven different groups of stains that require consideration. The next step in the process is to classify these stains.

Figure 4.8 When the pillow leaning against the east wall is removed during scene processing, an additional pattern is located on the wall behind it. It will be considered as part of Group 5.

Figure 4.9 Not only was a pattern present on the east wall behind the pillow, a pattern was evident on the surface of the pillow that was facing the wall. It too is part of Group 5.

Figure 4.10 The top surface of the pillow found on the bed is stained as well. This is Group 6.

Figure 4.11 Above and to the right of Group 3 (the small circular and elliptical shaped stains) is another series of stains. Their size and directionality suggest they are a separate event, Group 7.

Step 3: Classify the Patterns

Classification is the core step in bloodstain pattern analysis. Considering one pattern at a time, the questions are: What kind of stain is this? Is this contact or spatter? Is it impact spatter or spatter produced by a cast-off action? To find an answer to these questions, the analyst must ask questions that are more precise about the characteristics of the stain being considered. Classification requires some form of criteria against which the questioned stain will be evaluated. In other words, what are the physical characteristics of shape, size, dispersion, orientation, etc. that I am looking for to differentiate one pattern from another? As discussed in Chapter 3, criteria are not the same thing as definitions. For example, the typical definition of a cast-off stain is a "stain created when blood is flung or projected from an object in motion or one that suddenly stops some motion." This definition does nothing to explain what characteristics the analyst used to conclude that the stain pattern was cast-off in the first place. There must be some set of articulated criteria against which each stain is examined.

Classification using established criteria is the key to a successful and objective analysis. Before the analyst can ever begin to consider a hypothesis in the context of the crime, he or she must know what kind of patterns are present. As Saviano pointed out, the focus is on the pattern itself with no attempt to infer the broader meaning of the pattern in the context of the scene.[12]

Using the decision map (see Figure 3.34 and Figure 3.41 in Chapter 3) and taxonomy introduced in Chapter 3, we will apply this idea of classification to the stains and pattern in the following example.

Case Example: Classify the Discrete Patterns

In Figure 4.2, Group 1 consists of the large stained area on both the vertical and horizontal aspects of the box spring. The stains are non-spatter, as they are not made up of small elliptical or circular shaped stains. The pattern is 15 to 20 in. in length on the horizontal surface, which connects and extends down the vertical surface. There is an accumulation of blood, without any specific shape, but conforming to the surface contour of the mattress as well as

aspects that lead from one point (the horizontal area of the mattress) to another (down the side of the mattress). The fact that the two areas are connected supports an initial decision to discuss both aspects as one. An accumulation of blood is present on the floor beneath this pattern as well.

Applying the decision map to this group determines that it is a non-spatter stain, leading us to Group B. It has regular margins, leading to Group B.2. There is no patterned deposit, leading to Group B.2.2. There is both movement with surface contours, Group B.2.2.2.1, as well as aspects of accumulation and absorption, Group B.2.2.1. Based on these characteristics, the pattern is best classified as a complex pattern — a flow and saturation. The pattern beneath this group (just beyond the edge of the pillow on the floor) is distinct but follows a similar decision map path, which leads us to a saturation/pool.

In Figure 4.3, Group 2 consists of the large stained area to the far left of the bed, just inside the door but before the hallway. Once again, there are no spatter-type stains present (circular or elliptical); there is an accumulation of blood conforming to the surface contour and absorbed into the carpet. The stain is not wholly blood, however, with evident particulate matter present to the south of it, which is visually consistent with vomit.

Applying the decision map, the stain is a non-spatter stain, leading us to Group B. It has regular margins, leading to Group B.2. There is no patterned deposit, leading us to B.2.2. It has aspects of absorption, Group B.2.2.1. Based on these characteristics, the pattern is best classified as saturation.

In Figure 4.4, Group 3 consists of hundreds of small stains evident on the wall above the mattress. A better view of these stains, as seen in Figure 4.6, shows that they are small elliptical and circular shaped stains, indicating they have been airborne. The stains are present across the east wall starting at the level of the mattress and centered on the mattress. The pattern extends out to either side at least 25 cm and up the wall at least 60 cm. Individual stains in the pattern range from sub-millimeter to approximately 3 mm. There are literally too many stains to count. There is evidence of a radiating effect. The radiating effect, however, is not defined, so we may be looking at overlapping stains from different events. The stains are not oriented in any linear or curvilinear deposition. Also missing are any individual large volume stains.

Applying the decision map to Group 3 the pattern is made up of spatter, leading us to Group A. It is not linear or curvilinear, leading to Group A.2. There is a radiating dispersion leading to Group A.2.1. There are no ringlets or vacuoles present. Based on these characteristics, the pattern is best classified as an impact pattern.

In Figure 4.4, Group 4 consists of the area involving the defects. Figure 4.7 shows the nature of these defects. Although impact spatter (small elliptical stains radiating from a central area) overlay this pattern, the primary stains observed are without obvious elliptic or circular components. The staining outlines the defect as well as covers the depressed area, creating a pattern effect.

Applying the decision map to Group 4, the stain is not spatter, leading us to Group B. Although the pattern is more easily defined by the defect, the blood along the edges indicates a patterned appearance more than an irregular margin, leading us to Group B.2 and B.2.1. Based on these characteristics, the pattern is best classified as a pattern transfer.

When the pillow on the floor is removed, it reveals Group 5 as seen in Figure 4.8. Starting approximately 20 in. up the floor and extending to the floor is an accumulation of blood that has generally regular margins and leads from one point to another following the force of gravity. Additionally when we remove the pillow, we find similar staining on the top portion on the back side (see Figure 4.9). The staining includes an absorbed accumulation of blood with generally regular margins that extends down the pillowcase following gravity.

Applying the decision map to Group 5 the stain is a non-spatter stain, leading us to Group B. It has regular margins, leading to Group B.1, and movement with surface contours without absorption (on the wall), which leads us to Group B.2.2.2.1. There are aspects of movement and absorption, however, on the pillow (Group B.2.2.1). Based on these characteristics, the pattern is best classified as a flow and the pattern on the pillowcase is classified as a flow and saturation.

In Figure 4.2, Group 6 consists of the stains on the pillow on the bed. Figure 4.10 gives a more complete overview of this group of stains. On the top surface of the pillow is a large accumulation of blood, which extends outward to the left. The accumulation has absorbed into the fabric of the pillowcase and underlying pillow.

Applying the decision map to Group 6 the stain is a non-spatter stain, leading us to Group B. It has regular margins, leading to Group B.2, and both movement with surface contours (Group B.2.2.2.1) as well as aspects of absorption (Group B.2.2.1). Based on these characteristics, the pattern is best classified as a complex pattern — a flow and saturation.

In Figure 4.4, Group 7 is the set of large stains to the right of Group 3. A closer view of these stains is seen in Figure 4.11. Once again, we see a series of elliptical and circular shaped stains. The pattern consists of at least 12 individual stains ranging in size from 3 to 10 mm. They are all generally circular and show evident directionality slightly down and left to right. The size of these spatter stains compared to the spatter associated with Group 3 is distinctly larger. They show no radiating effect. There is no evidence of individual large volume droplets (e.g., flows from individual stains). The stains do have directional angles that run generally parallel to the overall pattern (left to right) and there is a somewhat progressive change in the shape of the stains, (the further right in the pattern they are found, the stains become more elliptical), although this is not distinct.

Applying the decision map to Group 7 the stains are spatter, leading to Group A. There is a linear arrangement evident, leading to Group A.1. There is no volume in the stains (no flows from individual stains), leading to Group A.1.2. There is a progressive change in the shape of the stains, although it is not distinct, leading to Group A.1.2.1. Based on these characteristics, the pattern is best classified as a cast-off pattern.

In these initial steps, the analyst first familiarizes himself with the entire scene so he knows where the bloodstains are. Next, he attempts to distinguish discrete patterns among the various bloodstain surfaces. Once this is accomplished, he classifies these discrete patterns using a viable (physical characteristic driven) classification system. These first three steps are always accomplished in sequential order.

Steps 4 and 5 are accomplished as needed and in varying orders, depending upon the situation. Certain aspects of these steps have already been considered when trying to define the discrete patterns in the scene, but are revisited to ensure validity of the initial analysis.

Step 4: Evaluate Aspects of Directionality and Motion for the Pattern

The questions posed in this step of the process are relatively simple. They include: From which direction did the stains being considered originate? Is there motion indicated by the stains? Information of this nature will be significant at later stages when considering the flow of events and actions in the crime scene. Evaluating directionality obviously aids in establishing area of origin for impact spatter patterns, so it is often evaluated simultaneously with Step 5. Nevertheless, direction and motion are not solely issues for spatter patterns; various drip, contact, and flow patterns require this consideration as well.

Case Example: Evaluating Directionality and Motion

Group 1 was classified as a flow and saturation pattern. The accumulation of the pool/saturation led to the flow and the aspects of the flow follow gravity, moving down the side of the box spring.

Group 2 as a saturation pattern demonstrates no obvious direction or motion aspects.

Group 3 was classified as an impact spatter pattern. By looking at the individual directional angles of the stains around the periphery of the pattern, we can see they are moving upward and outward away from the central area of the pattern, which is situated nearly centered on the mattress. The shapes of the stains in the central portion are more circular, indicating they struck at less acute angles (more closely to 90°). So the pattern is radiating out and away from an area somewhere low on the wall, just above the top side of the mattress.

Group 4 was classified as a pattern transfer, which demands some form of contact. In this situation, the direction of contact is more a function of the depression associated with the pattern than of the contact pattern itself.

Group 5 was classified as a flow pattern and saturation. The flow follows gravity, but its immediate source is not evident.

Group 6 was classified as both a flow and saturation. As the pillow is positioned in the final scene, the flow extends from the primary saturation, left toward the doorway and wall.

Group 7 was classified as cast-off. The individual stains show evident directionality slightly down and left to right. This, of course, is based on the long axis of the stain and the evident tails on the right side.

Step 5: Evaluate Point of Convergence and Area of Origin

Using the mathematical techniques explained in Chapter 8, the analyst seeks to answer specific questions relating to impact spatter. These include: Can an impact angle be determined for this stain? If so, what is it? Is there a point of convergence for a group of related stains? If so, can the area of origin be defined? If so, where is it? The answers to these questions can weigh heavily on the ability of the analyst to evaluate subsequent hypotheses in Step 7.

Often, when evaluating spatter patterns, it will become evident that the spatter involved is not from a single source event. Point of convergence and area of origin evaluations may indicate that there was more than one source event involved. This will alter the analyst's initial thoughts of what is a "discrete pattern," often requiring the analyst to break out and discuss separately the different spatter patterns that overlay each other.

Case Example: Evaluating Point of Convergence and Area of Origin

Group 3 was the only impact spatter pattern located. In Step 4, it was apparent that the stains are radiating out from a position somewhere centered on the bed. But in evaluating the stains, no clear convergence point is evident. Taken in consideration with the sheer number of overlapping spatter stains present in the pattern, this indicates multiple events were involved. Individual stains can be examined for their impact angle to validate the radiating effect observed. For example, stains centered and just above the level of the mattress show 70° to 80° impacts, while stains at the outer periphery of the pattern show impacts at acute angles down to 15°. Their directional angles all point back toward the center of the pattern, but there is no single point of convergence.

Any attempt to identify an area of origin from the pattern would be limited in value because the pattern suggests multiple impact events overlying one another. Lacking clear convergence points, it would be difficult to associate specific spatter to a specific event. If desired it could be done, but it would be difficult and provide limited information in the context of this crime. However, the overall radiating effect does indicate that the forceful events were occurring relatively low and centered on the bed.

After completing Steps 4 and 5, the analyst must now begin to consider what the patterns define together and then seek to explain the patterns in the context of the incident. To accomplish this, Steps 6 and 7 are considered in order.

Step 6: Evaluate Interrelationships among Patterns and Other Evidence

In this step, the analyst begins to look at the patterns in relation to one another and in relation to other items of evidence. Whereas in Step 3 the focus was on the individual pattern, here the analyst looks at the scene with a broader perspective. The questions posed include: Are any of the patterns related? Are they the result of a common bloodshed event? What do they define taken together? For instance, one often finds a cast-off pattern that clearly emanates from a spatter pattern. There may be a number of spatter patterns present on different surfaces that actually define a single pattern. Consideration and refinement of these answers can also alter the initial conclusions made in Step 2, for what was thought initially to be several distinct patterns might in fact be a single pattern.

Case Example: Evaluate Evidence/Pattern Interrelationships

Groups 1, 5, and 6 indicate that a free-flowing blood source was present in the room. Given their respective locations in relation to the victim's final position behind the door, they suggest a common source and sequential autonomous movement of that source from an area on the bed to the door. The first indication of the open blood source is present in contact with the pillow on the bed, with a flow pattern that extends in the direction of the wall and Group 5. Group 5 is very similar in its nature, but with no evident source above it or in contact with the wall. Group 1 shows the blood source was present low on the bed, but the source was not in contact with the bedding above Group 1.

Group 3 indicates multiple forceful impacts to a blood source while it was on the bed. The pattern transfer and defects in the wall support this. These defects show that blows were being directed at something but were missing. This occurred after the object being swung was already bloodied. The directional cast-off (Group 7) moves left to right and, taken in consideration with the orientation of the physical defects themselves, indicates the force was being applied from the north side of the bed (the left side).

The saturation/pool at the door (Group 2) is consistent with the final resting position of the victim's head and indicates she had a free-flowing blood source associated to her head. A check of autopsy information reveals that the victim from this room had numerous skull fractures, but no open lacerations or wounds. There are no connecting pools, associated drip patterns, or blood into blood patterns associated with the pool, indicating the source was on the ground and remained stationary after arriving here.

Step 7: Evaluate Viable Source Events in an Effort to Explain the Pattern

Using all of the information derived from the analysis in Steps 1 through 6, the stains and patterns must be considered in the context of the scene in an effort to answer the question: What caused these stains? This includes considering any unusual variables suggested by

the scene (e.g., extreme temperatures, wet vs. dry substrates). This step effectively leads us back to the direct application of scientific method, but at broader investigative issues. As Saviano suggested, the analyst must develop and test various hypotheses and theories related to the patterns in an attempt to explain their creation and any specifics they define about these events.[13] Additional information that must now be considered includes autopsy results (e.g., what types of injuries were received and where) as well as any DNA or serology results (e.g., whose blood is in the pattern).

In this step, when confronted with instances of unique issues or very specific crime scene conditions never before encountered, if the analyst is not comfortable with these considerations based on prior experience and training, this may require conducting specific research or experimentation in order to resolve a hypothesis.

Case Example: Evaluate Viable Source Events

Throughout the entire scene (the additional rooms in the house), repetitive pattern transfers are present, all consistent with the size and shape of the physical defects seen in this room (see Figure 4.12). These patterns as well as the defects suggest a bat-like object. The pathologist tests this hypothesis against the wound analysis. The pathologist supports this conclusion. No other wounding or patterns are present to suggest any other weapon.

In considering Group 4 (the defects with edges bloodied by contact), it shows that a bloodied object was directed in a N-S orientation against the wall. The defects and resulting contact pattern themselves do not specifically define a "bat," but they are consistent with such a weapon.

Group 7 indicates that a bloodied object was moved left to right (N-S) and slightly downward at a location above the mattress. The lack of heavy staining on the victim's hand eliminates any defensive action by the victim as a source of this pattern. The cast-off pattern is certainly consistent with that produced by a bat or bat-like object and the presence of the impact spatter in the area, as well as the contact patterns, supports that the weapon would have been sufficiently bloodied to produce cast-off.

Figure 4.12 Throughout the scene, a number of repetitive pattern transfers are found similar to this pattern. Combined with the wall defects and the similar pattern transfers on the wall and bed, they suggest a bat-like object was used as a weapon.

The blood source for Patterns 1, 5, and 6 are all consistent with a free-flowing blood source moving under its own power. This hypothesis is tested by verifying that the patterns are the victim's blood. The victim is verified as the source. Based on the sheer volume, it is apparent the source is flowing quite heavy, but there are no connecting transfer patterns or drag marks between them. This supports that the victim retained some mobility between these positions. At one point, the source was low to the ground in contact with and bleeding against the box spring. Lacking any other wounds, this places the victim's head at this location and would have exposed her back to any attack. Such a hypothesis, combined with our knowledge of the condition of the weapon (distinctly bloodied), allows us to immediately test it by considering her clothing. In examining the

Figure 4.13 Using scientific method, the scene suggests a position in which the victim's back was exposed to her attacker at one point in the attack. This begs the question: Is there evidence of additional attack to her back? The back of the victim's sweatshirt provides the answer, with numerous pattern transfers and directional spatter.

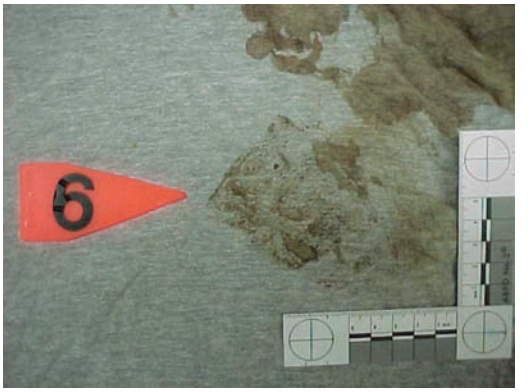

Figure 4.14 A close-up of a large pattern transfer on the back of the victim's sweatshirt. It has characteristics (size and shape) similar to those found in the east wall defects and the pattern itself is reproducible using a bloodied bat.

victim's clothing, a pattern transfer consistent with the class characteristics of the defects is located on her right rear shoulder (see Figure 4.13 and Figure 4.14).

Pattern 3 indicates a number of forceful impacts to a blood source that was centered on the bed. The only wounds that had the ability to expose a blood source are to the victim's head (flows from the nose or mouth based on fractures to the skull). There are seven physical defects on the wall behind the bed. Given the deposition of blood flows and pools that begin on the bed, this evidence supports a belief that the initial blood letting blows were delivered on the bed. Although no area of origin was calculated, the general convergence point of the spatter indicates the victim's head was in a position centered and relatively low on the mattress. The first contact point of the blood source is the saturation and pool on the pillow, which demands the victim's head was either in contact with the pillow or close to it after bleeding began. There are no drips or similar flow patterns on the sheets beneath the pillow, which effectively eliminates the pillow being raised off the bed.

Step 8: Define a Best Explanation Given the Data

In Step 8, all of the data presented are used in a broader sense to reconstruct the order and nature of the events associated with the bloodletting. In effect, we answer the question: What happened and in what order did it happen? Saviano eloquently described how the analyst moves from individual hypotheses to larger more encompassing theories, testing each objectively along the way.[14] Thus, the data from the bloodstains define conclusions about specific events, and through an understanding of individual events, theories of what happened can be formulated and tested in this final step.

A critical consideration in this final step is order of events. Sequencing and timing information from individual patterns is applied in an effort to define sequential relationships between stains. This effectively produces some level of order for the entire incident.

An area of concern in Step 8 is the injuries sustained by the various parties. The analyst should examine EMS, ER, and autopsy reports and photographs. The questions of concern

are the following. What bleeding injuries were present? Were arterial sources exposed? What level of mobility did the victim have subsequent to certain injuries? These considerations are discussed in greater detail in Chapter 6.

Case Example: Define a Best Explanation Given the Data

Based on all of the relationships discussed previously, the following is the best explanation of events given the data:

- The victim's initial bloodletting wounds were directed at her as she was on the bed.
- At one point, her attacker was to the north side of her bed, directing the blows N-S.
- The victim was positioned there long enough to allow multiple blows to be directed at her while on the bed.
- At some point after a blow or blows were struck, the victim began bleeding with her head in contact with the pillow. This occurred while the pillow was generally positioned as it is in the final scene.
- The victim was subsequently able to move under her own power and did so moving toward the north creating the flow onto the wall.
- Subsequent to dismounting the bed, she was low (kneeling) with her back exposed to the attacker and her head in contact with the box spring.
- She subsequently moved, was moved by another, or fell to her final position and was not moved again until the arrival of EMS.

The application of this methodology allows for objective analysis of the scene and bloodstains. Aspects of the analysis are deductive (e.g., classification and directionality). Later steps combine both deductive and inductive logic (e.g., associating specific actions to the stains). This blending of logic, using scientific method, allows us to ultimately arrive at defensible conclusions. Are there questions we cannot answer regarding this scene? Absolutely. Nevertheless, those actions that were identified have a foundation. So long as that foundation is accurate and we have considered all viable possibilities, we can remain confident of the conclusions drawn.

Applying the Methodology in Different Environments

There are three basic environments in which the bloodstain pattern analyst will apply the foregoing methodology. These are:

1. Active scenes: crime scenes where law enforcement is currently processing or has retained control of the scene subsequent to processing.
2. Released scenes: scenes involving ongoing investigations where law enforcement has documented the scene using standard processing protocols, but has released the scene back to the owner.
3. Cold case scenes: these scenes are similar to the released scenes; the only record of their condition is in the law enforcement documentation. Due to the time lapse since the event, the scene itself may have been significantly altered or destroyed.

Active Scenes

Active scenes offer the greatest opportunity for data collection to the bloodstain pattern analyst. If appropriate crime scene processing protocols are in use, then the scene context has not been destroyed by processing efforts. The bloodstain pattern analyst is able to enter and examine the scene *in situ*. The analyst follows the eight steps of the methodology as discussed, but his presence at the scene allows for more effective documentation beyond the basic crime scene documentation. It also ensures that stains and areas are not overlooked in Step 2 (Identify Discrete Patterns among the Bloodstained Surfaces). Just as important, the bloodstain pattern analyst can recognize and better understand spatial relationships of the scene, which can be important when considering Step 6 (Evaluate Evidence/Pattern Interrelationships).

In the active scene, it is imperative that the analysts understand their role in crime scene processing. Although this understanding is sometimes lost on the lab scientist, crime scene processing is not just showing up at the scene and bagging everything in sight. It has underlying direction and purpose. Crime scene processing protocols require that six activities occur. These are (1) assessing, (2) observing, (3) documenting, (4) searching, (5) collecting, and (6) analyzing. Since every action taken by the crime scene processing team ultimately alters the context of the scene, generally these activities are accomplished in sequence. The express purpose of this sequence is to engage in the least intrusive actions first, followed by the more intrusive (e.g., basic scene documentation is always accomplished prior to any physical search of the scene) and ensures that scene context is not lost as a function of scene processing.

If the bloodstain pattern analyst is present at an active crime scene, he should be trained in basic crime scene procedures and must recognize how his actions fit into this overall sequence. Thus, it is inappropriate for the bloodstain pattern analyst to show up at the scene and begin a procedure such as Roadmapping prior to basic documentation efforts. The analyst must understand crime scene concepts such as "going back," the process of stopping a procedure when new evidence is discovered and returning to earlier steps in order to document the new evidence. Most of the procedures the bloodstain analyst will attempt (e.g., road-mapping, point of origin determinations, bloodstain enhancements) are undertaken only after primary scene processing is accomplished.

If properly trained and on-scene, the analyst can directly assist in creating better crime scene and bloodstain pattern documentation. Areas for the analyst's consideration include:

- Pointing out small but important stains and patterns that might otherwise be left out of the basic documentation.
- Reminding individuals to photograph the victim and his or her clothing prior to depositing the victim in a body bag.
- Reminding individuals to photograph the areas that are beneath the body or beneath objects that were displaced in the room.
- Evaluating any suspects that are on scene for bloodstains on their bodies or clothing and then documenting their condition.
- Recognizing the need for enhancement of crime scene surfaces for latent blood.

Without a doubt, the active crime scene is the best scenario for evaluating the bloodstain scene. Released scenes and cold case situations present issues that ultimately limit the bloodstain pattern analyst to varying degrees.

Released Scenes

It is not uncommon for the bloodstain analyst to be called in to consult after an active scene has been processed and released. Although the basic methodology does not change, the analyst must recognize certain limitations inherent in this situation.

First, the analyst is no longer master of his own fate with regard to Step 2. The analyst can only analyze those patterns and stains that were documented, whether intentionally or not. The analyst should request and examine all photographic documentation by all parties. This includes photographs taken by first responders and ME investigators. It also includes any video footage taken of the scene. Keep in mind that oftentimes the crime scene processors will have a number of photographs that were not submitted to the DA or included in the final report. These photographs may have been considered of poor quality, redundant, or of no value in understanding the scene. Yet in these photographs, stains and patterns may unintentionally be documented that were not immediately evident to the crime scene processor for whatever reason.

The analyst should request all of the scene diagrams created by the original investigators. The crime scene sketches provide context to the photographs, eliminating some ambiguity. They often provide direct information regarding locations and distances associated with the evidence and particularly the bloodstain patterns.

The analyst should also request a complete list of recovered evidence. This list will identify what objects were taken from the scene and what is available for direct examination. Physical items taken out of the scene should be examined whenever possible, and the analyst should not merely rely on photographs of these items.

The scene itself remains a functional source of information. Granted, the context of the scene has been significantly altered during processing and certainly after release by authorities. Bloodstains, however, are a resilient type of evidence. Even after washing of surfaces, spatter stains may still be evident. Flows, pools, and saturation stains may be evident by examining beneath carpet, and enhancement of latent bloodstains is still possible. The analyst must consider any post-processing activity and how it may have affected or produced bloodstains in these aged scenes. However, a scene examination may still offer valid and helpful data.

Of interest to the analyst are spatial relationships in the scene. Crime scene analysts have long understood that spatial relationships are not immediately evident from examining two-dimensional photographs. A simple and purely innocent choice of lens or the angle in which a lens is oriented can make a very small space look quite large or hide the evident relationship of one surface to another. Thus, a scene visit can be helpful if for no other reason than to understand the spatial relationships present in the crime scene documentation.

Another source of data for the bloodstain pattern analyst are any notes prepared by the crime scene technician. These notes are prepared during the observation, documentation, and collection phase of processing. They should include detailed descriptions of the scene as observed by the crime scene technician. These notes are ultimately synopsized into a report, but in any ethical organization, they are retained as a part of the case file because

they are an original and contemporaneous record of the technician's observations and actions. Details regarding stains and patterns the technician did not consider pertinent for inclusion in the final report may be present in the notes. These additional details may functionally aid the analyst in understanding the nature and extent of various patterns.

After all is said and done, when dealing with a released scene the bloodstain pattern analyst may be left considering testimonial evidence as to the nature of stains and patterns. The analyst will often be presented with areas that were poorly documented with minimal photographic coverage. Obvious staining may be present, but the extent and overall nature of that staining will not be evident based on the photography. Detailed notes about these areas may not have been produced and the only functional source for information is the crime scene technician's memory. If the crime scene technician is considered an objective and knowledgeable source, the analyst may have to rely on his or her memory. This reliance should always be considered cautiously.

Cold Case Scenes

There is generally little difference between released scene circumstances and the cold case situation. The additional limitations in the cold case situation may consist of:

- No physical scene to visit. If enough time has passed, the scene itself may no longer exist or may have been significantly altered in some fashion.
- Investigative personnel who had direct knowledge of the condition and circumstances of the scene investigation may not be available for interview or too much time has passed and their memories are limited and of no value.
- There may be no physical evidence still in the possession of authorities associated with the case.

Beyond these limitations, the cold case is approached and resolved based on the crime scene documentation available.

Summary

Not long ago a Texas appeals court judge wrote "We are dubious of the claim in this record that blood spatter evidence can determine the aftermath of a violent incident of bloodshed and try to determine the locations of individuals before, during, and after bloodshed and to try and determine perhaps the sequence of events that occurred…"[15] The sheer ignorance of this statement still amazes anyone who has ever read it, yet it is a persistent mindset held by many in the legal profession. The proponents of this misinformation are furthered in their cause by a failure of this discipline to adequately prepare rank and file analysts to explain how they conduct their analysis using a structured approach.

A practical methodology is necessary for bloodstain pattern analysis and the analyst must be able to articulate how that methodology is applied. The purpose of such a methodology is to ensure that the analyst follows an accepted procedure based on scientific method. The failure to utilize a practical methodology will invariably affect the validity of the conclusions drawn.

One practical method of applying scientific method in bloodstain pattern analysis involves using the following steps:

1. Become familiar with the entire scene.
2. Identify the discrete patterns among the many bloodstained surfaces.
3. Categorize these patterns based on an established taxonomy.
4. Evaluate aspects of directionality and motion for the pattern.
5. Evaluate angles of impact, points of convergence, and areas of origin.
6. Evaluate interrelationships among patterns and other evidence.
7. Conduct supporting experiments when necessary and evaluate viable source events to explain the pattern, based on all of the above.
8. Define a best explanation given the data.

These steps effectively lead the analyst through the crime scene data, following the scientific method, to supportable conclusions regarding what the bloodstain data establishes. The basic methodology used by the analyst is no different when applied across the three different situations the analyst might encounter: active, released, and cold case scenes. The only difference to the analyst is in the limitations that the latter two situations may present to the analysis.

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The Medium of Blood

5

What is blood and how does it react to external forces? These are important questions for the bloodstain pattern analyst. Blood is a colloidal fluid. A fluid is defined as a substance that cannot maintain its own shape, but takes the shape of its container.[1] A colloidal fluid is simply a fluid that has solid particles suspended in it.

Fluids are generally incompressible. When force is applied to a fluid mass, it must displace in some fashion in response to the force. This concept is well recognized in science and is the basis of hydraulics.

Blood as a fluid is influenced by both cohesive forces (e.g., surface tension and viscosity) as well as disruptive forces (e.g., air resistance, gravity, and external application of force). The cohesive forces operate within certain parameters in all human beings; for instance, viscosity of healthy human beings ranges between 4.3 and 4.7. Surface tension affects similar molecules in a similar fashion. Just the same, disruptive forces (e.g., air resistance and gravity) operate within certain parameters no matter where the bloodshed event occurs. Thus, when an external force acts on a mass of blood, the mass will respond in a generally predictable fashion. For this reason, the patterns produced by fluid blood are reproducible phenomena.

Based on this predictability, in bloodstain pattern analysis we can differentiate broad pattern types created from six basic mechanisms:

1. Blood dispersed through the air as a function of gravity (e.g., drip, drip trails)
2. Blood dispersed from a point source by a force (e.g., impact patterns, expectorate)
3. Blood ejected over time from an object in motion (e.g., cast-off patterns)
4. Blood ejected in volume under pressure (e.g., spurt and gush patterns)
5. Blood that accumulates and/or flows on a surface (e.g., pools, flows, and saturations)
6. Blood deposited through transfer (e.g., smears and pattern transfers)

In trying to understand these characteristic patterns and evaluate specific patterns at the crime scene, it helps to understand some general cause-and-effect relationships. It is not our intent to suggest the bloodstain pattern analyst must be a fluid dynamics expert; that is not necessary. However, recognition of the general behavior of fluid blood is quite helpful to our understanding.

Before dealing with the six mechanisms, we will consider general aspects of spatter droplets in flight and on impact. Of the six mechanisms, four produce patterns in which the primary stains are spatter (circular or elliptical stains resulting from droplets of blood put into free flight). A fifth mechanism produces patterns that can involve significant numbers of secondary spatter stains. Thus, a majority of the bloodstain patterns of interest include these spatter stains. It is important that we understand the general behavior of free flight droplets that produce these stains because this behavior directly affects two primary aspects of bloodstain pattern analysis: directionality and impact angles associated with spatter stains.

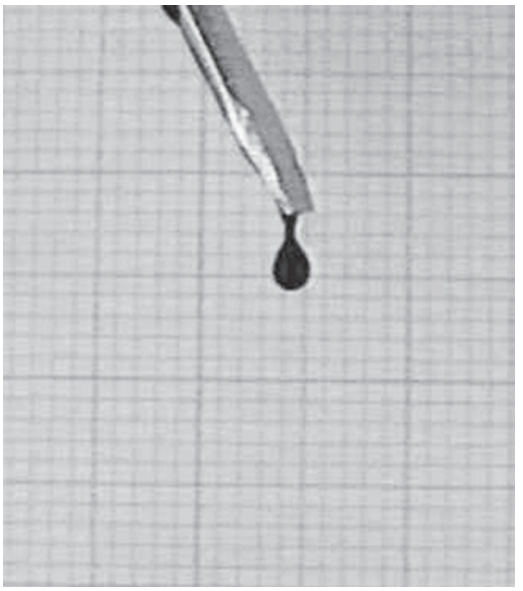

Figure 5.1 A drop forming on the tip of a screwdriver. At this point, the weight of the liquid droplet at the tip has almost overcome the ability of surface tension to hold it intact with the fluid running down the screwdriver. The droplet takes on a "tear-drop" shape as it stretches down and away from the tip. Although incorrect, this shape is often associated with blood drops and rain drops in flight. The structure connecting the mass and the fluid on the screwdriver is nothing more than a thin spine of fluid blood.

Spatter Droplet Dynamics

In flight, what characteristics does a blood drop have? It should be noted that previous authors have suggested that the information gleaned from raindrop research (water droplets in free flight) is not applicable to blood drops, as the former are a Newtonian fluid and the latter are a non-Newtonian fluid. The primary difference between Newtonian and non-Newtonian fluids is their behavior under pressure (a mass of fluid flowing in a tube). Despite these differences of flow behavior, the nature of blood drop behavior in free flight has, through empirical experiment and research, proven quite similar to that described for water drops, so we feel this research is applicable to our understanding.

Blood drops in flight ultimately achieve a spherical shape. James E. McDonald, in discussing raindrop shapes and answering why a fluid droplet is spherical, commented that "surface tension always tends to reduce the surface of a free mass of liquid to the smallest area it can achieve; an isolated drop of liquid not distorted by external forces is pulled by its surface tension into a spherical shape."[2] Dr. Alfred Carter also commented on the issue of shape and surface tension with regard to blood drops, stating: "With regard to the spherical shape of liquid droplets, it can be explained entirely by the surface tension of the liquid."[3]

Figure 5.1 and Figure 5.2 demonstrate liquid blood forming on the tip of a screwdriver and the subsequent detachment of a single drop. As evident in Figure 5.1, the forming droplet while still attached to the mass on the screwdriver takes the shape of the teardrop. Once fully detached, this shape is generally spherical. The droplet is not a perfect sphere, as the droplet is oscillating while in flight (see Figure 5.2).

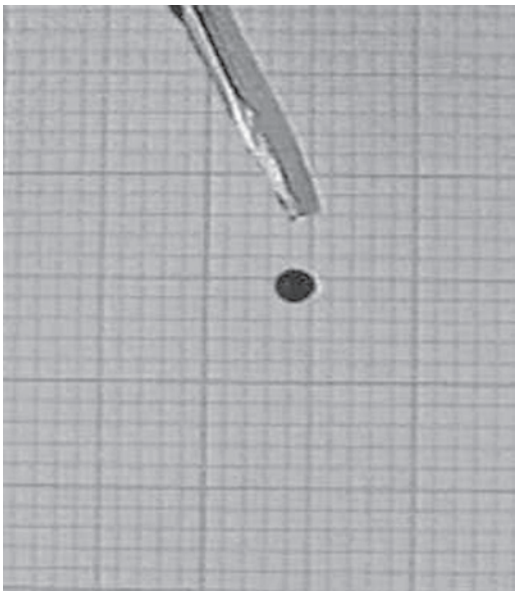

Figure 5.2 The weight of the droplet has overcome the force of surface tension in the connecting spine structure and the droplet is now detached. Once in free flight the droplet is generally spherical, although it is oscillating.

In considering how the force of surface tension affects fluid droplets, McDonald found that small droplets (1 mm in diameter and less) were almost perfect spheres. Larger drops, however, were unable to maintain a sphere shape in flight and often resembled nothing less than a "hamburger bun."[4] These oscillations in the mass can cause significant alterations in the shape of the drop. Surface tension acts to shape a droplet into a sphere, but surface tension is not the only factor involved in reducing these oscillations. As many authors have noted, water droplets oscillate to a great extent when falling in air. The surface tension of water is considered to be 70 dyn/cm, whereas blood has a surface tension of only 50 dyn/cm.[5] If surface tension alone were the only force damping these oscillations, we might well expect blood droplets to oscillate considerably. In fact, they do not, based on their viscosity.

To understand these oscillations, imagine for a moment that we could sit our droplet on a table (like a water balloon) and that it would retain its shape. If pressure were applied to either the side or top, the shape of the droplet would change to accommodate the liquid volume moved by that pressure. The volume would not change, only the shape. While in flight, oscillations in droplets have the same effect on the shape, but the force for change comes from within the droplet. Initial oscillations of the blood mass in a droplet are created when the drop is dispersed at the blood source.

The closest analogy we can offer is that like a wave, once produced the oscillation moves through the mass of the droplet, rebounding within it. The resulting change is cyclic; that is, it causes a range of recurring deformations from the perfect sphere. This results in a somewhat evenly distributed shape deformation (see Figure 5.3). Once initiated, this oscillation rebounds in the mass, but is constantly eroded or damped by the force of surface tension and viscosity. As a result, the level of this deformation will decrease over time. Just like water droplets, the smaller the blood drop, the faster the oscillation will damp and disappear (see Figure 5.4).

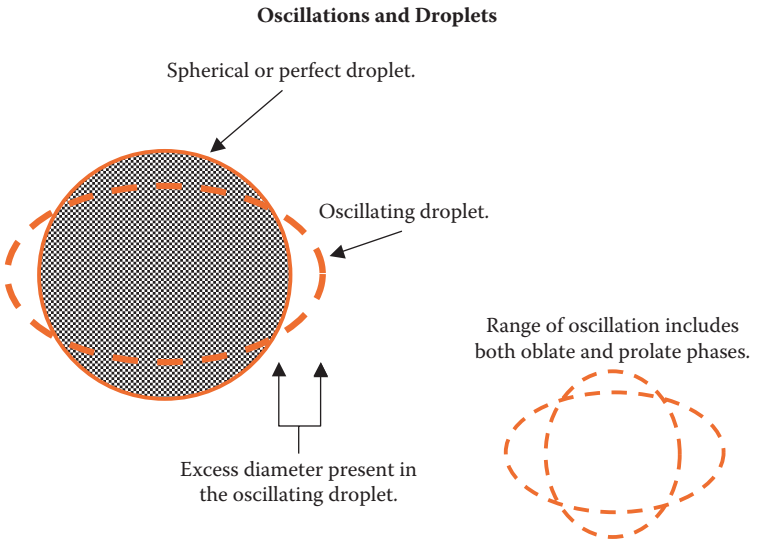

Figure 5.3 Oscillations in droplets. Because of their formation, droplets oscillate. This causes a shift of the droplet's mass from a perfect sphere to an oblong spheroid. The oscillation is dynamic; that is, it shifts until the oscillation decays completely. As such, the droplet moves through a wide range of shapes as the oscillation shifts back and forth between the oblate and prolate phase.

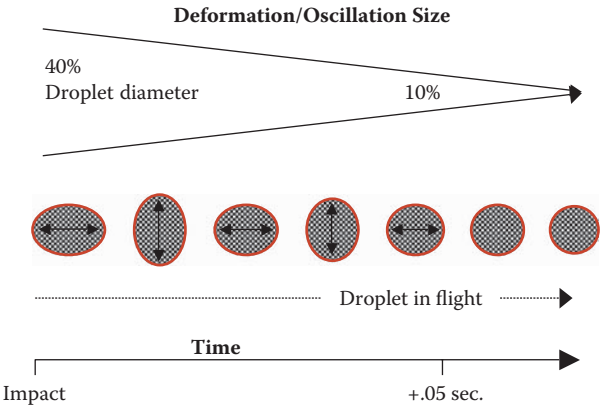

Figure 5.4 Oscillations in droplets move through an entire range of deformations. The most important aspect of the oscillations is that they decay with time. The longer the droplet is in flight, the smaller the remaining oscillation.

Spatter Drop Dynamics on Impact

The behavior of a blood droplet is to seek a spherical shape as it follows a given flight path to its destination. What happens when that spherical shaped droplet impacts a given surface? What the human eye cannot see, the human mind often cannot fathom. So it is with blood droplet impacts. Almost every author has commented in some fashion on what occurs during impact. In many instances, false cause-and-effect relationships were established. Although these beliefs do not deter our understanding of the resulting stain, they are still in error. A particular point of contention is what occurs when a droplet impacts a

rough surface. Nearly everyone, including your authors, has previously reported that droplets burst on contact when a rough surface ruptures the droplet's surface.[6–8] This certainly seems logical, but it is incorrect.

The behavior of the droplet as it impacts a surface defines the ultimate shape of the resulting stain and leads to the characteristics of a spatter stain, or a circular or elliptical stain. The following observations provide a greater understanding of the dynamic shifts of the droplet at impact and how these result in this characteristic shape.

Over a 2-year period, Gardner studied impacts using both stroboscopic photography methods and stop-motion video. The droplet impacts involved varying targets including coarse sandpaper, rough weave fabrics, poster board, and Plexiglas. Impact angles were varied as well. As a result of these observations, four distinct phases of the impact were identified.[9]

Some analysts may object to the specific labels used to describe this action, but what cannot be disputed is the physical action of the droplet during each phase. These phases appear independent of surface texture or impact angle, although all of these issues have some effect on the process. The phases, although slightly different on different surfaces, occur in all impacts. The only caveat we make with regard to these observations is that there appears to be a point of diminished volume for very small droplets at which the later phases are altered. The Weber number in physics is a dimensionless number proportional to the amount of kinetic energy in a fluid drop, divided by its surface tension energy. A blood droplet with a mass of .05 ml (e.g., a single passive drop) has a Weber number of approximately 160. Extremely small blood drops have much smaller Weber numbers and, as Carter reported,[10] studies suggest that if a Weber number were low enough, a droplet could theoretically retain its shape (not collapse) and could rebound off a surface, much like a drop of mercury. This may explain why in very small droplet impacts (e.g., those associated to misting stains) rarely is directionality noted in individual stain shapes. The Weber number is too low and the drops simply impact without collapsing as they do in larger drops.

In considering the observations, accept them as empirical observations, which help us understand the shift and transition the droplet goes through to create a stain. The authors choose to call these four phases of impact Contact/Collapse, Displacement, Dispersion, and Retraction. For ease of discussion, the following assumes a solid substrate or target. Liquid targets do not dramatically change the considerations of the phases, but unnecessarily complicates them.

Contact/Collapse

This phase begins when the droplet (a sphere) contacts the substrate or target. The droplet begins to collapse in a very orderly fashion, from the bottom up. Those sections of the sphere not in direct contact with the target remain intact and generally unaffected until they too collide. As a result, halfway through the collapse one would see half a sphere or droplet centered about the point of impact.

As this collapse occurs, the blood present at the collapse point is forced outward creating a rim around the droplet. This rim or boundary grows as more of the droplet's mass is forced into it. The flow to the rim has been referred to as an "involution"; however, it does not appear to fit that definition because the blood flows outward instead of inward.[11]

The angle of impact affects the contact collapse phase by defining the nature of the rim and blood flow into it. For instance, in a stain impacting at 90°, the blood flow into the

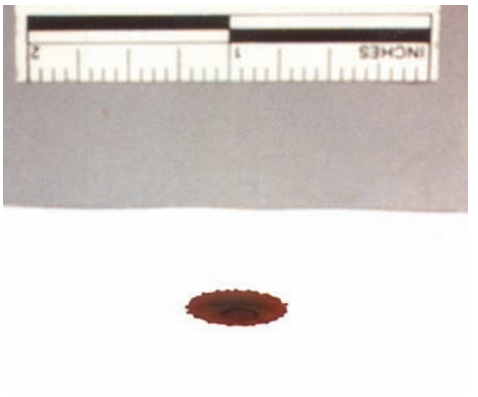

Figure 5.5 A droplet in late contact/collapse phase. A small dimple is evident in the center of the developing stain. It is what is left of the still collapsing droplet.

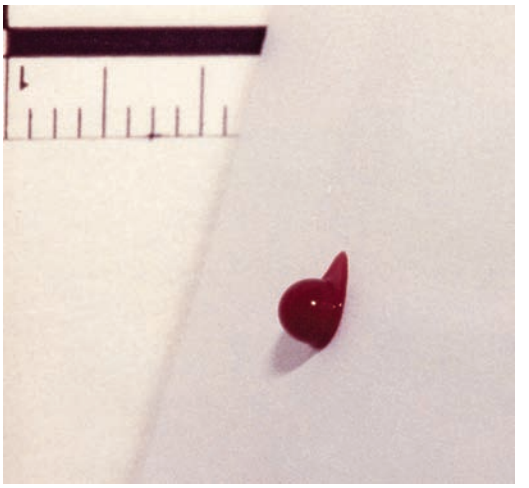

Figure 5.6 Early contact collapse in an acute angle impact. Note that the droplet retains it shape as it collapses from the bottom up.

rim is equal on all sides (see Figure 5.5). As a result, we see a circular stain with a generally equal diameter.

In stains impacting at more acute angles, the droplet's momentum forces the blood from the collapse into a more directional outflow. Consider an impact at 20°. Although the rim is still evident across the entire periphery of the expanding stain boundary, the blood is flowing primarily into the area of the rim opposite the direction from which the droplet originated (see Figure 5.6 and Figure 5.7). This directional outflow in combination with the droplet's skimming movement during collapse helps explain the elliptical shape of the stain.

Surface characteristics have an influence on the contact collapse phase. Surface irregularities found on rough targets can initiate an irregular outflow of blood in the collapse; however, this irregular outflow is far more evident in the displacement phase.

Displacement

In this phase, the sphere itself has collapsed against the target and the majority of the blood from the droplet has displaced to the boundary rim of the resulting stain. Dr. Balthazard, in his early efforts, also noted this particular phase or condition.[12] To this point, there is no apparent disruption of the surface tension. The droplet, although exposed to considerable shifts in its shape, is still one mass and has not broken apart.

Often evident on the boundary rim of the collapsing droplet are smaller developing droplets or short spines (see Figure 5.8). These appear to form as a result of the blood displacing from the central portion of the stain into the rim. These may eventually lead to the creation of satellite spatter during the next phase of the impact. The central area of the stain retains some blood, resulting in a sheet of blood that connects the entire structure. Nevertheless, nearly all of the liquid volume of the original droplet is now within the structure of the rim.

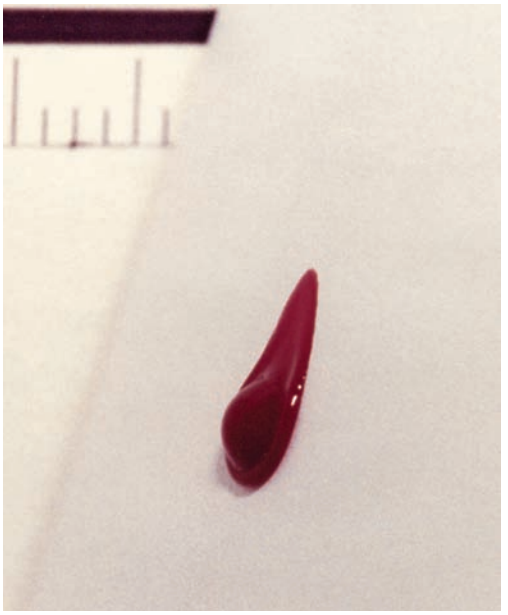

Figure 5.7 Late contact collapse in a droplet impacting at an acute angle. In this photograph about half of the droplet is still intact and evident in the center of the expanding stain. Note that the majority of the blood is being forced into the rim opposite the direction of origin.

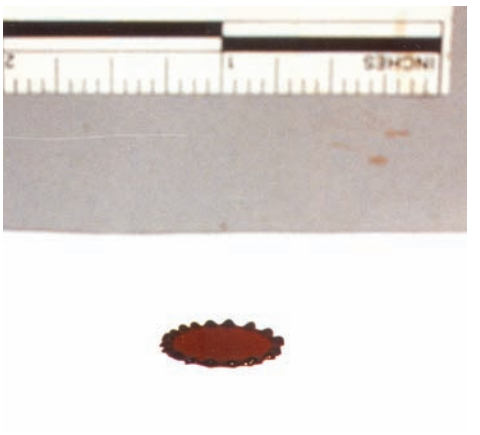

Figure 5.8 Displacement phase in a 90° impact. Note the displacement of the liquid to the rim of the developing stain. All motion up to this point in the collapse is lateral (outward).

Although displacement is only the second phase of the impact, it is interesting to note that the area defined in the displacement phase typically defines the overall dimensions (excluding any spines) of the resulting stain. If the liquid laterally displaces 4 mm in this phase, the resulting stain will measure 4 mm. It is important to note that displacement does not occur on a 1:1 ratio. That is, a 4-mm diameter droplet does not create a 4-mm stain. We have yet to define the true nature of this displacement ratio, but it is often as much as 270% of the droplet's diameter in large drops (e.g., a 4-mm droplet can create an 11-mm stain). We believe the displacement ratio drops as the volume drops, but this area also requires further study.

Impact angle affects the displacement phase only in the nature of the developing protuberances that will ultimately spawn satellite drops. As was evident in the contact collapse phase, 90° impacts result in development of a symmetrical rim. Thus in displacement, the small developing droplets may also appear symmetrically, surrounding the entire rim. Acute-angle impacts lead to these protuberances only in the forward edge of the developing rim. A single developing droplet, as found in a 10° to 20° impact, results in the classic wave cast-off stain. For example, Figure 5.9 exhibits displacement prior to the development of any protuberances.

Any of these small protuberances in the rim evident in displacement can result in an individual satellite spatter or spine. For instance, in 50° impacts one often observes a bear claw effect in the resulting stain. Each claw is the result of a single spine and each spine results from a protuberance that developed in the rim.

Figure 5.9 Early displacement of a droplet impacting at an acute angle. Note the distinct rim in the forward edge.

The surface texture of the target plays a prominent role in the displacement phase. It is not that a rough target surface "bursts" the droplet, resulting in the irregularly shaped stains we often find. In fact, the typical balloon analogy is severely lacking. In the balloon analogy, the skin is not an integral part of the fluid. In the blood droplet, however, the "skin" created by the surface tension is actually the fluid. It does not burst; it simply shifts its shape.

Because of this shift, the blood flows irregularly into the rim on a rough surface. The volume in one part of the rim may be large, while in another it may be small. The spines that form will also be irregular based on this difference in volume. This irregular outflow will usually result in an abnormal or asymmetrical collapse of the entire structure later in the retraction phase.

The end result is what analysts would likely call a distorted or excessively spattered stain. Figure 5.10 shows stains created by similar droplets falling the same distance,

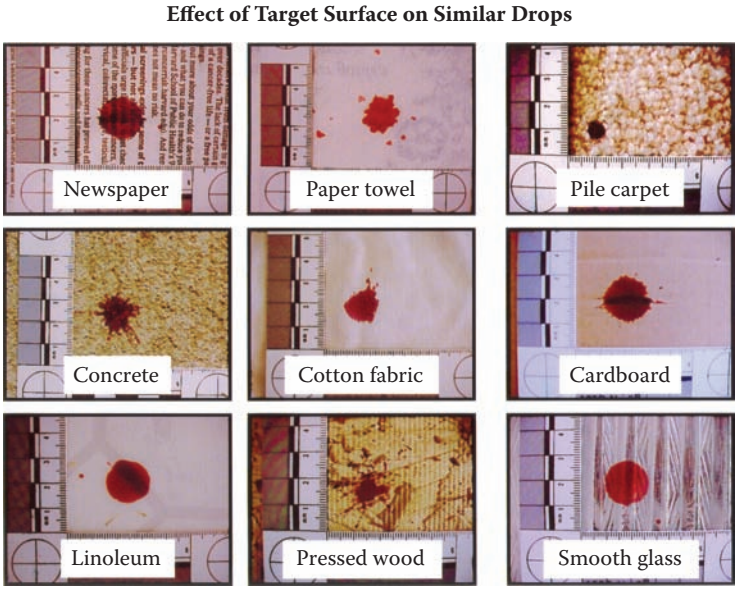

Figure 5.10 Target surface and stain shape. Target surface characteristics affect the shape of the resulting stain. The smoother the surface, the more likely the stain will be symmetrical with fewer satellite spatter. The rougher the surface, the more likely the stain will be asymmetrical.

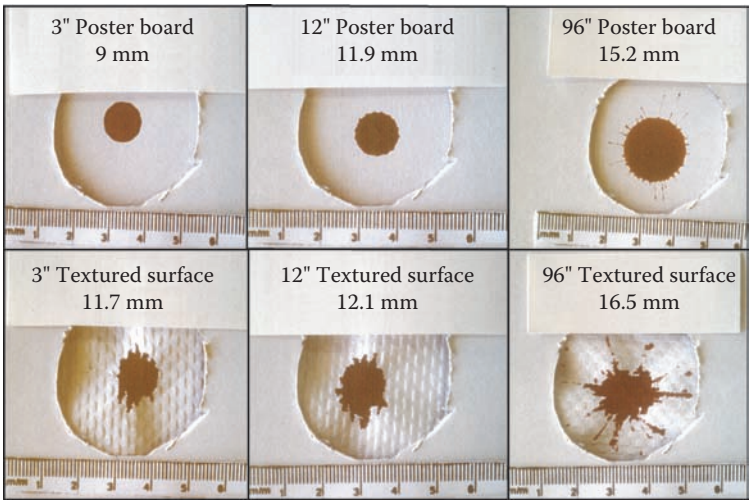

Figure 5.11 The further a gravity-induced droplet falls, the faster it falls up to its terminal velocity. The result of this increase in velocity is an increase in the resulting stain size. These drops (all of equal volume) fell 3 in., 12 in., and 96 in., respectively, onto the two target surfaces. The size of the stains increases with the increase in dropping height for nearly all surfaces, with the exception of significantly absorbent targets (e.g., carpet).

but to different surfaces. The droplets falling to the rougher surface display distinct distortion. We can never totally ignore the effect of the target surface on the collapsing droplet, as it may limit subsequent analysis.

Droplet velocity also plays a role in the displacement phase. As other authors have indicated, terminal velocity is reached for a given droplet when the effects of gravity are countered by air resistance.[13] This results in a constant velocity.

If we drop similar volume drops from different heights, the resulting stains will exhibit different overall sizes, resulting from different levels of displacement. A stain caused by a drop falling 3 in. will be smaller than one caused by a drop falling 3 ft. This is due to the increase in velocity of the droplet as it falls. The farther it falls, the faster it falls, up to its terminal velocity.[14] However, dropping distance experiments also indicate that before the droplet reaches this terminal velocity, no further lateral spread (displacement) will be evident in the resulting stain. See Figure 5.11.

In the 1970s, analysts often made a correlation between the size of a stain and the distance that it fell. These conclusions were based on the effect of velocity on the droplet (e.g., the lateral spread in displacement) as they had learned in their bloodstain classes, but this presumed a constant volume for a drop. Subsequent efforts show that the volume of a drop varies greatly depending upon the nature of the surface on which it forms. The more surface area available, the more blood volume in the resulting drop. Unfortunately for the analyst, the many combinations of droplet volume and droplet speed leave too many variables for this knowledge to be of any precise use in analysis. The only point we can conclude is that increasing the velocity beyond the terminal velocity (as in the case of spatter drops projected out by some force) does not cause a greater displacement of the droplet.

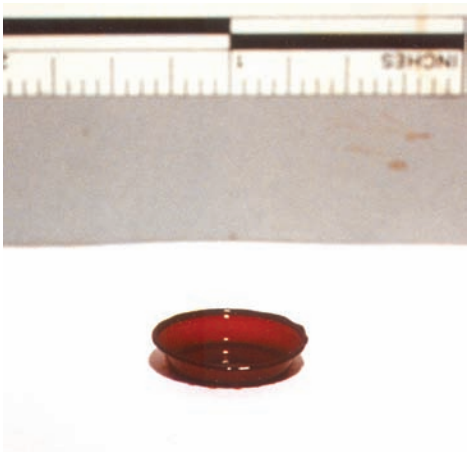

Figure 5.12 Early dispersion in a droplet impacting at 90°. Note the surface tension is still intact although the droplet's mass has shifted dramatically.

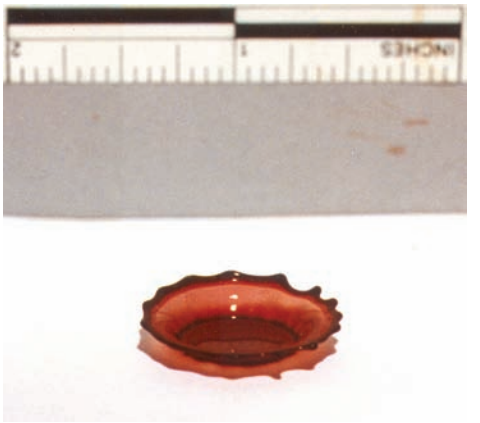

Figure 5.13 Late dispersion. Note the small dimples present on the rim of the blossom. In some cases, these may detach and cause satellite spatter. Also, note that the movement of the liquid in the dispersion phase is upward and outward.

Figure 5.14 A classic wave cast-off developing during the dispersion phase in an acute angle impact.

Dispersion

The dispersion phase offers a glimpse at perhaps the most elegant behavior of the droplet during impact. Results include the crown or blossom effect in near 90° impacts. See Figure 5.12 and Figure 5.13.

Figure 5.14 shows the dispersion phase in an acute angle impact. The development of the droplet at the end of the emerging spine is often referred to as a wave cast-off. Although often reported, there is no whip or backlash effect evident in the wave cast-off.[15]

This phase is easily categorized by the action of the rim. Blood is forced into the rim and protuberances, which now rise upward. As the volume of liquid in these structures increases they become unstable. If sufficient force (inertia) is present, the structures break apart, resulting in the creation of satellite spatter.

The angle of impact plays an important role in defining the dispersion phase. In droplets impacting at or near 80° to 90° the result is a blossom effect. In this instance, the rim and protuberances rise upward

around the entire periphery of the stain (refer to Figure 5.12). Whereas in displacement the motion of the liquid was lateral, in dispersion it is upward and outward.

In stains impacting at the more acute angles, the blossom builds more like a wave on one side of the rim. This wave in turn creates one or more spine-like structures. As the wave builds, surface tension once again pulls the liquid together. This causes a droplet to form at the end of the wave. As the wave and droplet rise off the target, surface tension pulls the liquid (which is still in motion) up and away from the target. This action results in the edges of the mass pulling toward one another, which closes the end of the ellipse of the resulting stain. Any spines present in these instances extend out beyond the rim and often spawn a satellite droplet. That is to say that at the end of each spine, one may observe a small droplet.

Even at the end of the dispersion phase, surface tension is still a viable force seeking to maintain the connection between the main mass, spine, and satellite droplet. How much upward dispersion (the blossom effect) occurs appears to be tied to the nature of the target surface. In some instances this upward movement appears quite distinct, and in others less so. This variable certainly requires further study, but has no effect on our understanding of the stain shape or directionality.

Retraction

The retraction phase is the final phase in the development of the stain. It appears to result from the effect of surface tension attempting to pull the fluid back into a single form. The inertial forces that caused the shifts in the droplet's mass are now either overcome by surface tension resulting in a complete retraction of the liquid, or these inertial forces overcome the surface tension present in the spines resulting in the formation of spine or scalloped protuberances from the main stain and/or satellite spatter.

At the onset of the retraction phase, it appears that two forces attempt to counter one another. Inertia of the droplet developing at the end of the spine forces it away from the central stain; at the same time, surface tension attempts to retract the liquid present in the spine. Particularly in acute-angle impacts, if the inertial forces are sufficient, each spine will be stretched beyond the ability of surface tension to hold the fluid intact. Given these opposing forces, satellite droplets routinely detach. It is only at this point in the overall impact sequence that the surface tension of the droplet is actually overcome (e.g., bursts), resulting in the creation of satellite spatter.

The blood retracted to the parent stain then coalesces and levels itself across the stain to some degree. A thick outer rim is usually evident, both in the wet or dried stain (see Figure 5.15).

The angle of impact has some effect on the resulting stain in the retraction phase. For instance, in the 80° to 90° impacts no part of the blossom's structure (excluding any spines) is responsible for the stain's ultimate length or width. The structure of the blossom completely retracts to the original boundary evident in displacement.

In the more acute-angle impacts, the majority of blood present in the spine retracts to the parent stain, but in many instances remnants of the spine simply fall to the target. The spines create the "tadpole tails" and scalloped "claws" we so often see in elliptical stains (see Figure 5.16).

Although roughness or irregularity of a target has little effect on the outcome of the stain during retraction, some target characteristics do matter. Of particular concern is whether the surface is of a wetting or non-wetting nature. In the situation of a non-wetting surface, the

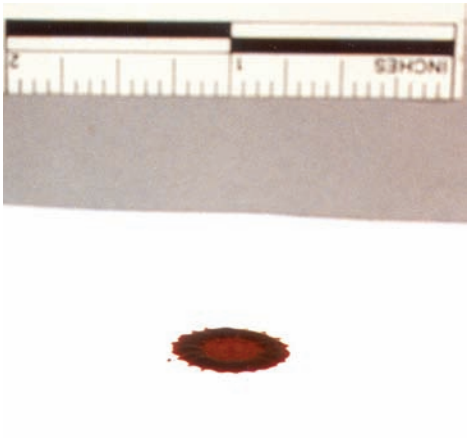

Figure 5.15 Retraction in a droplet impacting at 90°. The blossom we saw previously retracts to the area defined in the displacement phase.

symmetry of the stain may be irregular as a result of irregular coalescing of the liquid stain. Absorbency of the target can also play a prominent role in affecting this symmetry.

In summing up our observations on the phases of impact, Figure 5.17 graphically depicts all four phases for varying impact angles. We recognize these observations will not change an analysis, but they do allow the analyst a better understanding of why the resulting spatter stain looks as it does.

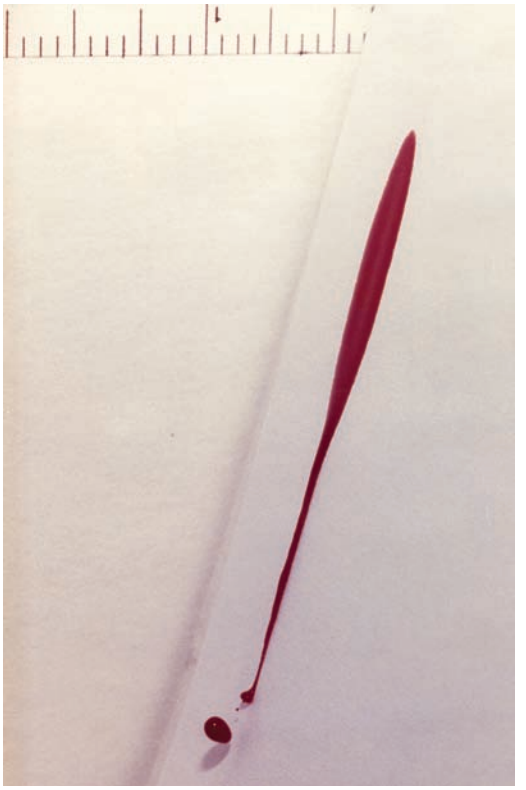

Figure 5.16 Retraction in an acute angle impact. As the spine attempts to retract, inertia of the satellite droplet overcomes the surface tension in the connecting spine resulting in the complete detachment of the satellite. The spine simply falls to the target, creating a tail.

Liquid-to-Liquid Impacts

For the most part, considering liquid-to-liquid impacts serves little function in bloodstain pattern analysis. The resulting patterns produced by such events are generally lost to the pooling in which they occur. However, in some instances such as blood into blood patterns, understanding the differences of these interactions may assist the analyst.

The four phases occur during liquid-to-liquid impacts but with differences. No major differences were noted for the contact/collapse phase. The droplet still collapses from the bottom up.

In the displacement phase, however, there appears to be more blood forced into the expanding rim. Blood present in the target flows into the rim in addition to the blood from the droplet. This is true in instances where the impact occurs into a pool of blood or even another drop of blood. Figure 5.18 shows an example of this abnormal blossom development.

Because of the increased volume and lack of a solid target, we see a less defined displacement phase and an early development of the dispersion phase. The blossom is far more

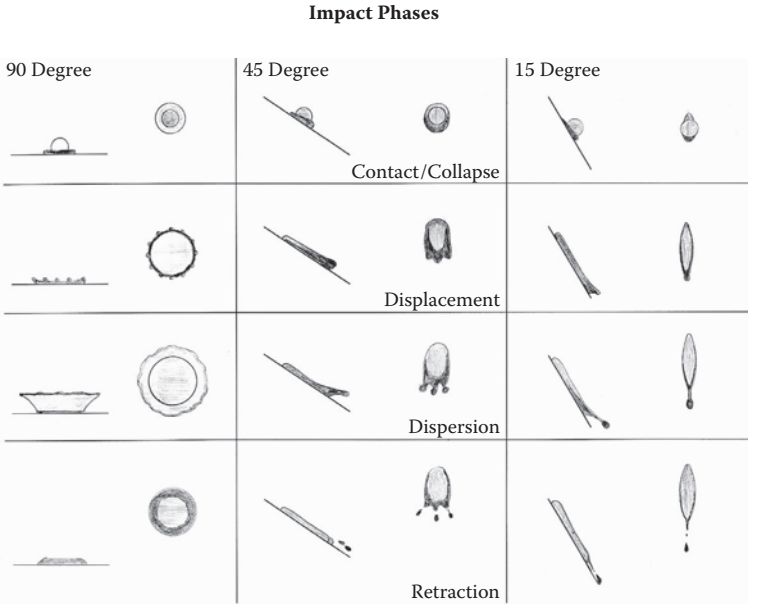

Figure 5.17 A graphic showing all four phases of impact as they occur in varying angles of impact. The drawing on the left side of the box depicts the view from the side; the drawing on the right of each box depicts the view from overhead. What is evident from this figure is that the collapse of a droplet is far from a simple "drop and burst" effect.

pronounced and has been said to resemble a sea anemone.[16] The protuberances are also more pronounced and always result in satellite spatter. In near 90° impacts, these spatters are thrown off in nearly every direction. This result is quite evident in the classic drip pattern, where satellite spatters surrounding the pool extend out several inches from the central pattern.

In retraction, the only added result of a liquid-to-liquid impact is a rolling motion that develops in the pool. If other droplets impact the target while this motion is evident, the dispersion of the satellite spatter is even more random.

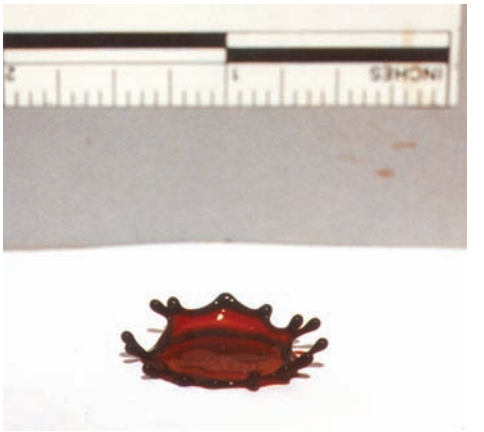

Figure 5.18 Dispersion in a liquid-to-liquid impact. One drop has fallen into another; the increased liquid in the rim often leads to an abnormal outflow of blood and an asymmetrical development of the blossom.

Blood Behavior When Exposed to Different Mechanisms

As previously noted, there are six basic mechanisms that become evident through the analysis of bloodstain patterns. Four of these mechanisms produce patterns in which the primary stains are spatter. They are:

1. Blood dispersed through the air as a function of gravity (e.g., drip, drip trails)
2. Blood dispersed from a point source by a force (e.g., impact patterns, expectorate)
3. Blood ejected over time from an object in motion (e.g., cast-off patterns)
4. Blood ejected in volume under pressure (e.g., spurt and gush patterns)

Having considered the creation of spatter and spatter stains in general, let us now consider how blood behaves when exposed to specific creation mechanisms.

Blood Dispersed through the Air as a Function of Gravity

If a sufficient volume of blood collects on any object (e.g., a weapon, a hand, or any surface), free flight drops of blood can be produced. As gravity pulls the fluid mass downward, the volume at the tip of the drip site will start to shear from the mass. This shearing first produces a teardrop-shaped drop that is connected to the drip site by a small spindle of blood (refer to Figure 5.1). When this spindle is stretched beyond its ability to remain intact, it shears and the surface tension of the detached mass retracts it into a spherical shape. This retraction of the spindle by surface tension sets off an oscillation in the droplet. If the spindle breaks apart, small satellite drops form (known as follow-on drops) from remnants of the spindle that are not retracted to the drip site or coalesced to the newly formed drop.

Volume and flow to the drip site are integral factors that affect the size of the drops produced by a drip. As the rate of blood flow into the drip site increases, the volume in the individual drops tends to increase. Conversely, MacDonell observed and reported that a simple reduction in the rate of flow will not result in significantly smaller drops. The surface area on which the drip develops is important to drop size formation as well. MacDonell first associated a volume to the "typical" passive drop, placing this number at approximately .05 ml.[17] Subsequent authors would call into question this number, rightfully challenging that, given the variations in surface area on which a drop might form, there really is no "standard" drop size. Surface area is a critical factor in the resulting size of the stain. Smaller surface areas (e.g., knife tips, ice picks) do not allow as much volume to accumulate before gravity breaks the blood mass free. Larger surface areas (e.g., arms or a knife blade held level) will create significantly larger drops. See Figure 5.19.

There are limits to the maximum volume of a passive drop. This limit is based on the volume that is present in the largest stable free flight drop. Volume is of course a function of size and, for blood, the maximum size of any stable free flight droplet observed is about 5.5 mm in diameter. Thus, the maximum volume for a stable passive drop is approximately .06 ml.

If there is an upper limit for the size of a droplet produced by gravity alone, is there also a lower limit? Research indicates there is. For drops with volumes of .010 and .011 ml, the developing drops routinely stabilized on the tip of the object on which they were forming. Surface tension of the blood, however, holds this developing drop to the surface. By introducing minimal oscillation (e.g., simply tapping the object) to these small volumes, the forming droplet will release easily. A drop with a volume of .012 ml will form and release without any inducement other than gravity. Below this volume (a range somewhere between .009 and .012 ml) gravity alone simply does not have enough effect on the mass present in the forming drop to overcome surface tension.

This range of volume for passive drops provides us with an understanding of why there is a tendency for stains produced by drips to be larger than those seen in other spatter-type

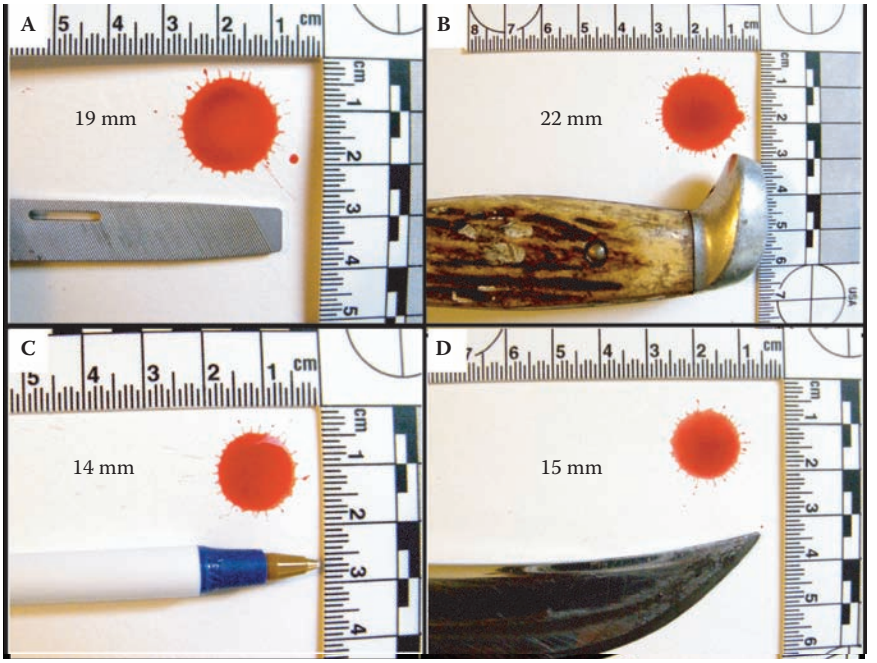

Figure 5.19 Surface area is important in determining the size of the resulting stain. The larger the surface area available, the more blood that can collect. In this figure are four objects and the stains produced by a natural forming drip from each object. The drips were all produced from the same height. Photo A is a flat file and produced a 19-mm stain. Photo B was the broad hilt end of the knife. It resulted in a 22-mm drip. Photo C is a typical writing pen. Blood dripping from the tip produced a 14-mm stain. Photo D is the tip of a knife, which produced a 15-mm stain.

mechanisms (e.g., impact and cast-off). Gravity induced drops tend to be large. The drops in flight are 3 to 5.5 mm in diameter, resulting in relatively large spatter stains that may measure as much as 25 mm in width. Keep in mind these are the parent or primary stains. Satellite stains associated with the droplet's impact or break-up of the connecting spindle (follow-on drops) are much smaller.

Blood Dispersed from a Point Source

If a mass of blood is struck by some external force or pulse (e.g., a hammer strike), the mass will displace in response to the application of that force. This displacement also results in the generation of spatter. Figure 5.20 demonstrates this type of displacement. The photos are from the video production "Blood in Slow Motion," created by the Metropolitan Police Forensic Science Laboratory. The photographs capture the blood as it is being struck and actively displaced. In Figure 5.20, Frame A, a sheet of fluid blood is expanding out from the surface where the hammer head struck. Several distinct spindles and projections are evident breaking out from this sheet, one to the lower left of the hammer head and one to the top right. The primary displaced mass, however, is generally intact, although undergoing extreme shifts in its shape.

In Frame B of Figure 5.20, a semicircle structure of blood is evident primarily to the lower right of the hammer and original blood mass. Both of the spindles of blood seen in Frame A appear to have impacted onto the target, close to the origin. Spiny stains are

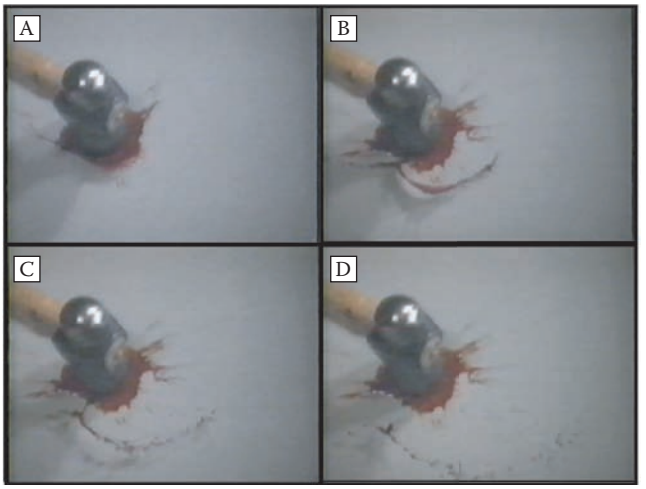

Figure 5.20 As an object strikes a mass of blood, the fluid must displace. In this photograph, the blood is ejecting primarily to the top right of the hammer head. (Photograph courtesy of the Metropolitan Police Forensic Science Laboratory, London, England.) In the next photograph, the blood ejected to the top right of the hammer head is continuing to break apart and ultimately will become primarily spatter. (Photograph courtesy of the Metropolitan Police Forensic Science Laboratory, London, England.)

observed on the target where they struck. The primary mass of blood is still in flight. Note that surface tension is still an active force trying to hold the mass of blood in a single mass. However, as it displaces outward the mass is stretching and expanding.

In Figure 5.20, Frame C, this mass has expanded beyond the ability of surface tension to withstand this force and it breaks up into smaller masses that become drops. Surface tension is still active in each of these smaller masses and will ultimately shape them into stable droplets. By Frame D, most of this separation into droplets is complete. Note that the droplets are radiating outward, like spokes on a wheel.

Figure 5.21 shows another impact at a source point, but better demonstrates the behavior of the small masses produced by these impacts. In this instance, blood was caught between two pieces of a board. Note the spindle structures moving out away from the source, which was situated to the left of the photo. As they expand, these spindles rapidly shear into droplets. As the inertial forces acting against the cohesive forces of surface tension and viscosity tear the structures apart, evident oscillations are introduced into the resulting drops.

One point for consideration is that one can never predict accurately and fully where spatter will or will not eject. In Figure 5.20, spatter is ejecting to the lower left and upper right of the head of the hammer as a function of the interaction of the hammer and the target. If the contact had occurred in a different fashion, the resulting dispersion cone of ejected spatter may have been dramatically different. The manner of contact and the paths available for the blood to displace away from the origin will define the resulting spatter dispersion.

The size of the resulting spatter produced by impact at a point source is important. Impacts result in relatively small drops. While studying impact events, we documented droplets (not the stain) with diameters ranging between 0.125 and 2 mm. Volumes for

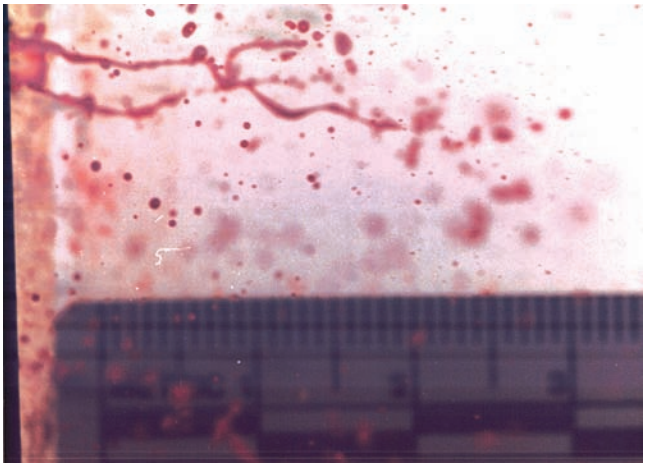

Figure 5.21 Another example of blood displacing due to a force. A mousetrap device to the immediate left of the photograph displaced the blood. As it displaces, spine-like structures are still evident as well as droplets. The spines will degenerate into droplets when the force of displacement overcomes the surface tension and viscosity of the liquid blood in the spine.

such impact droplets are quite small (under .007 ml). We are not saying this range is an absolute for all impact events. The size range of droplets in any given impact event will vary depending upon the nature of the impact involved. Nevertheless, empirical research and considerations of stain size and droplet volume place the upper limit of this range at about 2 mm for droplets formed by an impact event. We found that the droplets that create stains 4 to 5 mm in size have diameters generally not larger than 2 mm.[18] The average diameter of the droplets produced in this particular study was .6 mm. In 1997, van Netten and Dewey, in collaboration with the Royal Canadian Mounted Police, Edmonton Identification Support Section, sought to find a reliable photographic method of documenting spatter. Their stated purpose was to establish the size and velocity of these small droplets. As a result of their efforts, the Canadian study found very similar results. Their work, entitled "Blood Spatter 2," reported on droplets created because of an impact to a blood pool. The size range of droplet evident in the study was .26 mm up to 1.45 mm in size. The average diameter reported was .74 mm.[19]

The most important point to make in this information is that when considering impact events we are looking at relatively small droplets that, as Ryan noted, oscillate at a much lower level. This is important because with but one major exception these oscillations have little effect on issues in bloodstain pattern analysis. The exception is in considering impact angle determinations, a standard practice directed at patterns produced by impact at a point source. The definition of impact angles, in part, is based on the belief that a droplet impacting a surface is in the shape of a sphere. If a blood droplet were oscillating to any great degree when it impacted a target, the resulting deformation in the droplet's shape could alter the stain's ratio of width to length. Given this instance, the analyst could not rely on the resulting angle determination.

We asked Dr. Kenneth Beard to comment on oscillations in blood droplets and their effects. In considering this issue, Dr. Beard stated:

> Blood droplets should have initial oscillations of a rather large amplitude since the forces in the disruption process are not spherically symmetric. These oscillations will damp significantly in a fraction of a second for droplets of a few millimeters in diameter. Disruption of blood flow at the source of droplets should be the primary cause of oscillations since the forces from other influences are generally weaker (for example that associated with air motions). It seems unlikely that droplets would collide far away from the source, to produce additional oscillations, because they become dispersed.[20]

Dr. Beard provided calculations for defining droplet oscillation, which allow greater insight into droplet behavior.[21] He also indicated that a liquid's viscosity is a critical element in damping any oscillation in the droplet. The higher the viscosity, the faster is the damping of the oscillation.

Based on this information, we know that oscillations in blood droplets damp about four times as quickly as oscillations in water droplets. One cannot absolutely discount these oscillations as unimportant. At the initial impact point, they may be quite distinct (up to 40% of the droplet's diameter), but the time it takes these oscillations to die out is relatively short.

Subsequent research with blood has supported Beard's basic predictions. Raymond, working with pipette-produced droplets, noted oscillations of up to 10% of the droplet's diameter.[22] Gardner, working with droplets created by impact, found similar data in which the majority of oscillations damped below 10% of the droplet's diameter within 0.05 s after impact.[23] Thus, the viscosity of a blood droplet helps eliminate oscillations, allowing surface tension to form the drop back into a more perfect sphere. After initial disruption at the source, droplets in flight will tend to maintain this spherical shape with few factors present to disrupt them further.

In summarizing these concerns about droplet size, oscillations, and any resulting deformation of the blood sphere in flight, we can say that droplets created as a result of an impact at a point source:

- Generally have diameters no greater than 2 mm
- Have oscillations present in the mass of the liquid, but these oscillations damp very quickly
- These oscillations are created from the initial break-up of blood and no further forces are present after break-up that might induce additional oscillations
- When impacting a target, such droplets are close to being perfect spheres, which allows a level of confidence for the width and length ratios of the resulting stains

Blood Ejected from an Object in Motion

If a mass of blood is transferred to some object (e.g., a hand, a weapon), the blood will adhere to the object. If the object is then put in motion (accelerated), the blood mass adhering to it will initially displace with the object as a function of the acceleration. As the object accelerates, the force holding the blood mass to the object (surface tension) may be overcome. If this happens, a droplet is released and continues at a tangent relative to the movement of the object. If sufficient blood is on the object, this release of droplets will occur repeatedly at different moments and different points in space. These droplets then

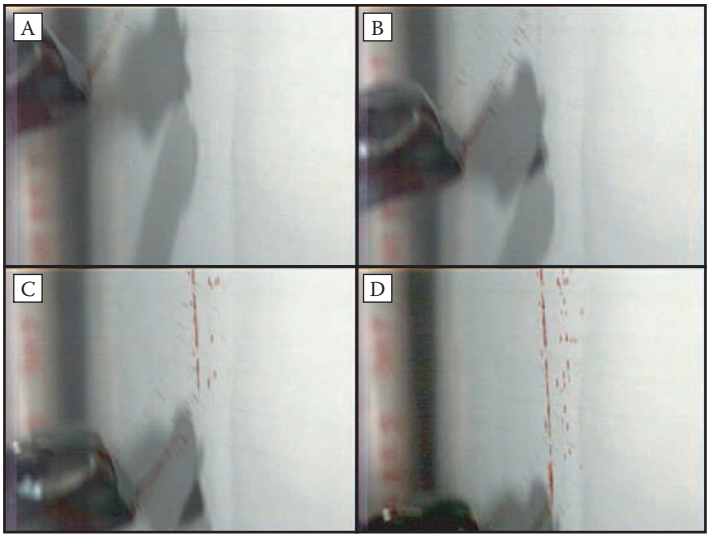

Figure 5.22 A cast-off event. In Frame A, blurred droplets can be seen ejecting from the object's surface. In Frame B, the individual drops are more recognizable. In Frame C, the object is nearly perpendicular to the target and drops are seen impacting in lines. In Frame D, two distinct lines of stains are evident.

impact surrounding surfaces creating linear patterns of stains. The blood is said to be "cast-off" from the object.

Figure 5.22 shows a four-frame sequence of cast-off. In Frame A, the cast-off object (a swing arm rotating on a stable pivot point) can be observed in the upper left corner. Individual drops (blurred by their motion) are seen ejecting from the top of the swing arm. In Frame B, the individual drops are more recognizable, but none has struck the target. In Frame C, the swing arm is nearly at a 90° angle to the target surface and drops are seen impacting and producing lines of stains. In Frame D, the swing arm is nearly out of frame and two distinct linear patterns of staining are evident on the target.

The size of the spatter associated with any given cast-off event is a function of the volume of blood available and the surface area on which the blood collects and is released. In most instances associated with cast-off events, the droplets produced will be stable drops similar to those produced by impact. However, there are instances in which, if a significant volume is present on the object, the droplets produced will be large as well. In such instances, even cast-off can produce large stains with flows coming from the individual stains (see Figure 5.23).

Blood Ejected in Volume under Pressure

If a volume of blood is put under pressure through some mechanism and the avenue of escape for the blood is channeled, the result is a stream of blood put into flight as a mass. As that mass encounters air resistance and the effect of gravity, it will shear into smaller masses and ultimately droplets. Both the unstable masses and droplets impact surrounding surfaces, producing large volume linear patterns.

Figure 5.24 shows a mass of blood ejected from a tube attached to a hypodermic. As the blood ejects in a stream, it is a connected mass. Air resistance and gravity act against the

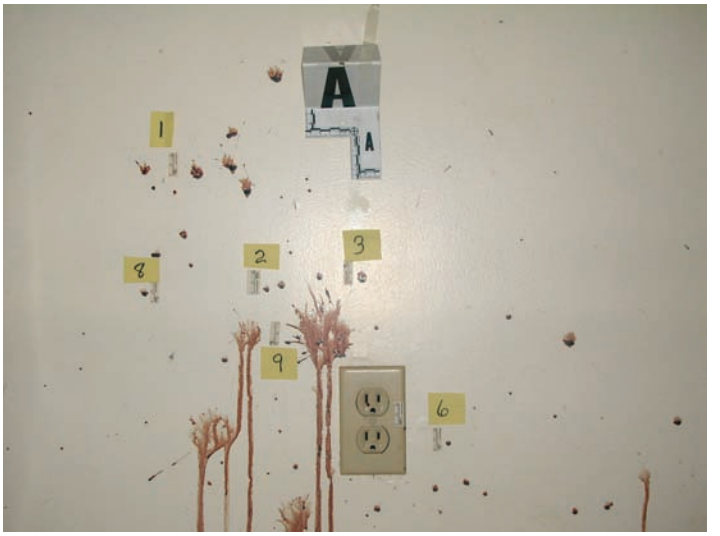

Figure 5.23 In most instances, the droplets produced by cast-off are stable drops and create distinct circular or elliptical stains. If sufficient volume is present, the cast-off drops are also of a greater volume and can mimic the types of spatter observed in spurts and gushes (large stains, with flows coming from the stain). This pattern was produced by cast-off from the hands of an individual who was clearing the mouth of a gunshot victim who had a significant blood volume in the mouth.

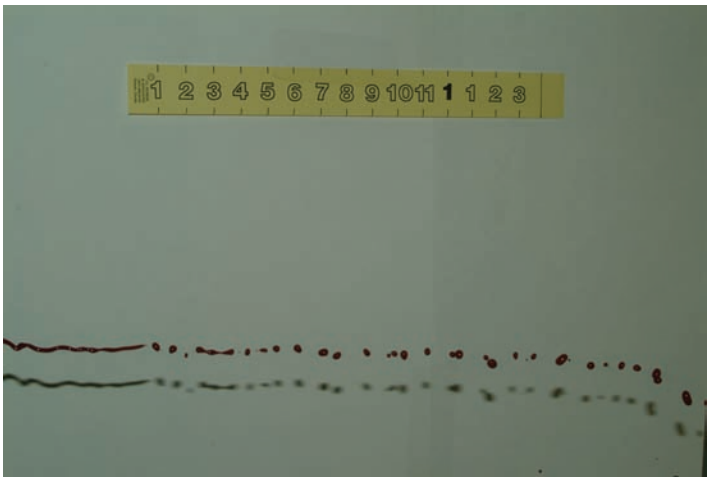

Figure 5.24 Blood ejected from a hypodermic with a small plastic tube attached to the end. Volume ejections are streaming ejections that break up over time through the effect of gravity and air resistance. This initially produces large less stable masses, which if in flight long enough will break up into stable drops.

mass shearing it into smaller masses and droplets. The farther it flies, the more likely it will break up into stable drops. Arteries, the primary source of blood ejected in a stream, behave in a similar fashion. Figure 5.25 shows a temporal artery ejecting blood under pressure.

The most common form of streaming ejection is blood ejected from a breach of an artery; however, other less common mechanisms may also produce a stream of blood and produce similar patterns. Examples include impacts into large volumes of blood on

Figure 5.25 Arteries that are breached produce streaming ejections and are the primary source of most spurt patterns. In this instance, the source of the stream is a temporal artery ejection. (Photograph courtesy of Lt. Steve Kohne, Tippecanoe County Sheriff's Office, Lafayette, IN.)

Figure 5.26 Actions other than breached arteries have the potential to produce streaming ejections. In this instance, a significant volume of blood was present in the spatter and dispersed by a bat blow. Due to nothing more than the volume involved and the channeling of the blood, several streaming ejections were produced as well as impact spatter. (Courtesy of FBI Scientific Workgroup on Bloodstain Pattern Analysis, Quantico, VA.)

a hard surface. If the displaced volume is channeled, it can produce a stream ejection (see Figure 5.26). Several odd medical conditions can also produce stream ejections. One example is venous insufficiency syndrome, which results in protruding varicose veins. If the vein is damaged, it will eject small volume streams under pressure.

The four mechanisms just discussed produce patterns in which the primary stains are spatter stains (small circular or elliptical stains). Two additional mechanisms are evident though a bloodstain pattern analysis:

- Blood that accumulates and/or flows on a surface
- Blood deposited through transfer

Blood That Accumulates and/or Flows on a Surface

Patterns created as a function of blood accumulating or flowing on a surface share similar basic characteristics; the primary stain will have an evident volume of blood present in it and will have regular margins. Note that we say primary; such patterns may well have additional secondary stains including a large number of spatter or spines. But the primary stain will be a volume accumulation of some nature. The typical mechanism of blood accumulations include pooling, flowing, and saturations. Additional mechanisms involve volume ejections and blood dripping into blood.

Pools and flows simply accumulate as a function of gravity and the container characteristics of the surface on which they occur. Saturations are similar but the pooling occurs on a permeable surface; thus, the volume is less evident having been absorbed.

Volume ejections of blood (e.g., an arterial gush) have such a significant volume ejected that no true break up of the blood mass occurs. These involve stream ejections under pressure, but the volume is ejected in such a fashion that it lands in a relatively confined area. Thus, the primary stain will have pool-like characteristics, but as it is an ejection, there is a significant level of interaction of the blood when it strikes a surface. Secondary staining in the form of spines and spatter will accompany the primary stain. Blood dripping into blood also results in a volume accumulation, but one produced through time. Once again, the primary stain will be a volume accumulation having pool-like characteristics, but accompanied by many secondary spatter surrounding the primary stain. The mechanism of blood into blood patterns is examined fully in Chapter 10.

Blood Deposited through Transfer

The final mechanism of interest in bloodstain pattern analysis is that of deposit through contact. These types of patterns are produced when blood adheres to some object and is then transferred through some form of physical contact to another object. Unlike spatter, cast-off, and stream ejections, the mechanics of transfer have not been studied as thoroughly as the results of such transfers, but these patterns are easily recognized based on their physical characteristics.

Summary

As we said in the beginning, it is not necessary for an analyst to understand fluid dynamics in order to understand bloodstain patterns. However, recognition of the manner in which a droplet collapses at impact is important for recognizing why we can establish directionality and why impact angle can be calculated effectively. Understanding the way that various dispersion mechanisms affect fluid blood allows the analyst to more readily understand why a particular pattern appears as it does and why differences exist between different patterns produced by different mechanisms. All of this leads us to being better prepared for classification issues.

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Anatomical Considerations in Bloodstain Pattern Analysis

6

MICHAEL FERENC

Introduction

To interpret a bloodstain pattern, the analyst should understand a modicum of biology. The details of blood, blood clotting, and associated bleeding disorders form complete medical subspecialties and are far beyond the scope of this chapter or the reader's patience. However, a brief overview of the subject may still be beneficial.

Blood Cells and Plasma

Human blood is a complex fluid with both liquid and suspended solid components. The solid components account for approximately 45% of the blood volume and consist of the following cellular components: red blood cells, white blood cells, and platelets. These cells are derived from precursor stem cells in the red bone marrow. The liquid component, plasma, accounts for approximately 55% of the volume.[5,13,14]

The red blood cell, or erythrocyte, measures approximately 7 to 8 μm (micrometer or one-millionth of a meter) in diameter and is approximately 2 μm in thickness. The red blood cell contains no nucleus but does contain hemoglobin. Red blood cells circulate for approximately 90 to 120 days until they wear out and are removed by scavenger cells in tissues like the spleen and liver.

Hemoglobin, the oxygen carrying protein in red blood cells, contains iron, which is responsible for blood's red color. The hemoglobin also is the basis for many of the presumptive blood tests used at crime scenes. The simplest, oldest, and least specific methods are based on the medical guaiac test. When hydrogen peroxide is dropped on a bloodstained swab or piece of paper impregnated with guaiac (gum guaiac is a green-brown tree resin), the iron in hemoglobin, acting as a reducing agent, promotes a blue color change to the guaiac (more modern blood testing techniques instead use an antibody-based color change reaction specific for human hemoglobin).[13]

Erythrocytes are normally biconcave disks. However, as a bloodstain dries on a target surface, the red blood cells first crenate (become shrunken and rounded with scalloped or spiky surfaces) and then hemolysis occurs (the cells rupture and break apart).

In medicine, an estimate of the number of red blood cells can be done in several ways. One way is to calculate the amount of hemoglobin per unit volume of blood. Normal values are approximately 12.5 to 15.0 g/dl (grams per deciliter or one-tenth of a liter) for women and approximately 14.0 to 17.5 g/dl for men. This is equivalent to approximately 4.5 to 5.1×10^6 red blood cells per microliter (or one millionth of a liter) for women and 4.5 to 5.9×10^6/μl for men. Another method is to centrifuge for several minutes a small glass capillary tube filled with blood. The heavier solid components (the cells) are pulled to the bottom and the liquid part is pulled to the top. As a percentage of the height of the volume of the blood in

the tube, the red blood cells normally are 38 to 45%. When expressed as a percentage of the total blood volume, this number is called the hematocrit. The hematocrit is approximately three times the hemoglobin value in normal circumstances. A very thin pale band forms between the plasma and red blood cells accounting for usually <1% of the total volume. This is called the buffy coat and contains the white blood cells and platelets.

Platelets, or thrombocytes, are another cellular component that lacks a nucleus. Platelets are 2 to 4 μm fragments that are released from a special bone marrow precursor cell (megakaryocyte). They survive only about 9 to 12 days in the circulation. Platelets are involved in the initial stage of hemostasis (the stopping of blood loss). On the inside of a blood vessel at an area of injury, platelets clump to form a small plug and release chemicals that trigger other parts of the clotting process. The average person has 150,000 to 450,000 platelets per microliter of blood. Spontaneous bleeding usually does not occur unless the platelet count falls below 20,000 per microliter.

White blood cells come in several subtypes such as lymphocytes, monocytes, and granulocytes. Each subtype serves a different role in fighting infections and regulating the immune system. White blood cells are nucleated and, thus, are the source of DNA for forensic analysis of bloodstains. The average person has approximately 4.4 to 11×10^3 white blood cells per microliter of blood.

Plasma is a straw-colored, viscous liquid and accounts for approximately 55% of the blood volume. It is composed of over 90% water with the remainder being salts, carbohydrates, proteins, lipids, and dissolved gases. A blood clot consists of red blood cells, white blood cells, and platelets enmeshed in the fibrin formed when coagulating plasma proteins interact. The remaining clear pink-yellow liquid is referred to as serum. Serum separation is often observed in a crime scene and appears as this pinkish-yellow fluid surrounding a large volume of coagulated blood.

Viscosity is a measurement of a fluid's resistance to flow. The viscosity of blood is due to both the resistance of the plasma (plasma alone is 1.5 to 1.8 the viscosity of water) and, primarily, the percentage of red blood cells. Viscosity of plasma and red blood cells is approximately 3 to 4 times that of water. A decrease in red blood cells below the normal values (anemia) reduces viscosity. For example, an otherwise healthy person can survive with a hematocrit as low as 21%. The opposite extreme of too many red blood cells (polycythemia) results in increased viscosity (a hematocrit of 60% is associated with a viscosity about 8 times greater than water).[12]

Coagulation and Hemostasis

Hemostasis is the process by which the body prevents or limits blood loss after injury. The three initial components of hemostasis are vascular smooth muscle spasm, formation of a platelet plug over the damaged endothelium (the inner surface lining of a vessel), and formation of a fibrin plug from coagulation factors in the plasma.[14,15]

The plasma contains a series of dissolved proteins (the classic major factors are numbered I through XIII), most of them made by the liver. When triggered, a complex coagulation cascade occurs, ending in the formation of a fibrin clot. The pale pink-yellow fibrin clot is a meshwork of interlinked proteins that blocks off or narrows the damaged vessel. If a particular factor is absent or abnormal, the formation of fibrin is prevented or significantly reduced. For example, deficiency of factor VIII is a common cause of hereditary hemophilia.

The coagulation cascade is sometimes described in terms of an intrinsic pathway or an extrinsic pathway. Some of the factors are unique to one or the other pathway. Substances released by the platelet plug and by the damaged blood endothelium activate the intrinsic pathway, while substances released from the disrupted tissues at the injury site activate the extrinsic pathway. The separation of these pathways is somewhat artificial, as there is quite a bit of interaction between the two (a factor VIII deficiency hemophiliac, whose intrinsic pathway is defective, can still form fibrin clots through the extrinsic pathway). The result by either route is a fibrin clot. The clotting process at an injury site begins almost immediately, and a small superficial cut can form a clot in approximately 1 to 3 min.

Competing with clot formation is the process of blood lysis (dissolving). Injured tissue also releases a substance (tissue plasminogen activator, TPA) that changes another plasma substance, plasminogen, into plasmin. Plasmin dissolves fibrin, allowing the body to break down portions of the blood clots and re-establish blood flow to the tissues. Examples of this effect can sometimes be seen at a crime scene. Very rapid blood loss where the escaping blood has had little or no contact with TPA will often result in typical clot formation. A slower rate of blood loss, where the blood has time to interact with TPA, may form pools of non-clotted liquid blood.

Individuals treated with anticoagulants for medical reasons are often referred to as being on "blood thinners." The blood is not actually thinned. Rather, the patient is given a drug that blocks or retards some part of clot formation. Examples include aspirin, which interferes with the release of a thromboxane, a substance needed to cause platelets to clump together. Coumadin blocks vitamin K. Vitamin K is needed by several of the coagulation factors to function. Heparin binds to a substance, antithrombin III, which blocks the conversion of several coagulation factors to their active forms. This in turn reduces fibrin clot formation. However, anticoagulants ("blood thinners") do not alter blood viscosity, the number of red blood cells, or the behavior of a bloodstain on the final target surface.

The Circulatory System and Shock

The average person has approximately 70 ml of blood for each kilogram of total body weight.[11] The variation of size and weight among different people means that the typical range of total blood volume is approximately 4 to 8 l (8 to 16 pints).[13]

Circulation is normally a closed-loop system. Blood is propelled from the left ventricle of the heart (with 90 to 140 mm Hg systolic [contracting] pressure, 0 to 8 mm Hg diastolic [resting], at a rate of approximately 4 to 8 l/min) into the aorta (approximately 120/80 mm Hg).[10] The aorta is one of several elastic arteries, so called because of the increased elastic fibers in its walls that expand and recoil helping to propel the blood along. The arterial tree branches out into smaller and smaller muscular arteries. The contraction or relaxation of the muscular wall of these arteries, and particularly arterioles (the final <0.5 mm diameter artery branches just before capillaries) can regulate the amount of blood flow to a particular region and the overall blood pressure.[7,15]

The capillaries are the smallest (approximately 7 to 9 μm wide and approximately 1 mm long) but most plentiful vessel. In the capillaries, the now slowed blood is able to diffuse oxygen and nutrients to the tissues and take away carbon dioxide and waste materials. This is also the leaky part of the circulatory system where liquids can move in or out of the circulation.[5] Any excess fluid that leaks out is collected by a parallel one-way system of

vessels called the lymphatics. The contents of the lymphatics eventually empty back into the circulation near the heart.

The capillaries join to form first venules and then larger and larger veins. Inflammatory processes also can make the venules leaky, allowing liquids and white blood cells to move out into the tissues. The veins have thin walls with a few muscle cells that allow for some contraction or dilatation. Veins are referred to as capacitance vessels and, under normal conditions at rest, can contain up to two-thirds of all the blood in the circulatory system. By merely standing up, each leg has the capacity to store an additional 350 ml of blood.[6] Many of the larger veins in the limbs have valves so that flow proceeds only one way, back to the heart. The superior vena cava and the inferior vena cava are the final large veins that empty into the heart's right atrium (pressure range approximately 0 to 8 mm Hg). From the right atrium, the blood is pumped to the right ventricle, which pumps the blood through the capillary bed of the lungs. There it is returned to the heart into the left atrium and then into the left ventricle to start the circuit anew.

The passage of blood through vessels can be described as turbulent or non-turbulent flow.[4,15,16] Turbulent flow is movement of blood in a non-parallel direction in the vessel, producing irregular whirlpools or eddies that often can be heard with a stethoscope. This type of flow occurs at branching points in vessels, as well as in diseased vessels. Non-turbulent flow is roughly parallel movement of blood in a vessel and is the most efficient means for perfusing tissues. Sometimes this efficient non-turbulent flow through larger blood vessels is described in terms of Poiseulle's law. Poiseulle's law concerns the laminar flow of an incompressible, uniform fluid (that is, a Newtonian fluid such as water) through a cylindrical tube with a constant circular cross-section. Laminar flow is where concentric fluid layers move in one direction with the innermost layer traveling the fastest (and the most efficiently). The mathematical details of this law are beyond the scope of both this chapter and this author. The relevant part of this law to bleeding issues concerns the resistance to flow through a tube. The key point is that if blood in a vessel is exhibiting laminar flow, then resistance to flow is inversely proportional to the fourth power of the radius of the lumen. If one assumes that at a constant vascular pressure, a cut vessel of 1 mm diameter loses 1 ml of blood per minute, then a cut vessel of 2 mm diameter would lose 16 ml of blood per minute, and a vessel of 4 mm diameter would lose 256 ml of blood per minute. Poiseulle's law and laminar flow appear to be useful in approximating the behavior of blood inside healthy larger arteries. However, blood vessels are not straight, are not uniform, and do not exhibit steady flow. Furthermore, blood is a complex fluid with liquid and solid components, not a Newtonian fluid. Any limited predictive value laminar or turbulent fluid dynamics has regarding blood loss ends at the tip of the cut vessel.

The condition known as shock occurs when there is insufficient blood perfusion to the tissues and organs to meet their physiological needs. Hypovolemic shock results from loss of circulating blood volume such as results from rapid bleeding. Other forms of shock include cardiogenic shock (e.g., a heart attack resulting in inadequate cardiac pumping) or septic shock (e.g., infectious process resulting in massive dilatation of most of the blood vessels all at the same time).

Sometimes hypovolemic or hemorrhagic shock is clinically separated into four levels.[11] The first is rapid blood loss (over a matter of minutes to a few hours) of less than 15% of the total estimated blood volume (EBV). This degree of blood loss is usually accommodated by an increase in cardiac output and constriction of the blood vessels without significant changes in heart rate or blood pressure. The second level occurs when blood loss is between

15 and 30% of the total EBV. This condition is associated with elevation of the heart rate to approximately 100 beats per minute (tachycardia), narrowing of the pulse pressure (the medical records will often say the pulse is "thready"), increased respirations (tachypnea), a slight decrease in blood pressure (hypotension), and anxiety. Any blood loss over 30 to 40% of the total EBV is associated with increasing tachycardia (over 120 beats per minute), greater tachypnea, worsening hypotension, decreased urine production, and mental confusion. Finally, when blood loss exceeds 40% total EBV, worsening of the vital signs, minimal urine production, sweating, constriction of the pupils, and lethargy will result.

The rapid loss of 30 to 40% of the total EBV in an otherwise healthy person is survivable, but requires the maximal use of all compensatory mechanisms such as increased heart rate, shifting of fluids from outside the circulation, and vasoconstriction. However, rapid loss of over 40% without immediate therapy is usually fatal. With this degree of blood loss, the circulation system cannot meet the needs of the body, and irreversible tissue death with multi-system organ failure ensues. Fluid resuscitation and aggressive medical therapy at this point may delay the inevitable but cannot halt the process.

When rapid blood loss is not replaced, initially the hemoglobin and hematocrit concentrations remain the same. Only after the circulatory volume is re-expanded with crystalloid or colloid fluids is the degree of bleeding reflected in the decreased hemoglobin and hematocrit (each 3% drop in the hematocrit is roughly equivalent to the number of red blood cells in a pint of blood). With blood loss over a prolonged period, such as days, a person can compensate for a loss of 50% of the total EBV through the shifting of extracellular fluids and increased fluid retention.[8]

Non-Traumatic Causes of Bleeding

One of the issues an investigator must consider at a scene involving bloodshed is the following: Is this a crime scene? A victim may be rendered susceptible to rapid, often-fatal blood loss from natural processes or incidental minor trauma. Here is a small sample of conditions that might be commonly encountered and mistaken as a crime scene:

From the head: Epistaxis, or nosebleeds, can sometimes result in severe and even fatal bleeding with the blood loss amounting to several pints of blood expelled in minutes. It can be a spontaneous process, due to hypertension, or due to drug ingestion such as cocaine. Simple lacerations in the very vascular tissues of the scalp can also lead to rapid blood loss with ensuing shock and death, especially if the victim is impaired such as from alcohol intoxication.

***From the lungs*:** Blood expelled from the lungs is called hemoptysis. It can result from medical disorders including infectious diseases or inflammatory disorders such as pneumonia, tuberculosis, or autoimmune diseases. Cancers can erode into blood vessels causing sudden and massive hemoptysis. In asphyxia or drug intoxications, pulmonary edema and bleeding within the lung tissues can result in copious amounts of bloody-looking fluid in the mouth and nose that may even cover the face.

Blood can be expelled from the airways during a cough at very high velocities and become atomized in the process. In one study[1] looking at the efficacy of paper masks, simulated coughing resulted in velocities ranging from approximately 5 to slightly over 13 m/s (roughly 16 to 42 ft/s). Another study[2] looking at cough-generated infectious aerosols found cough speeds ranging from 1.5 to 28.8 m/s (roughly 4.9 to 94 ft/s). Taking either set of values, a cough can propel blood at enormous speeds and should be considered

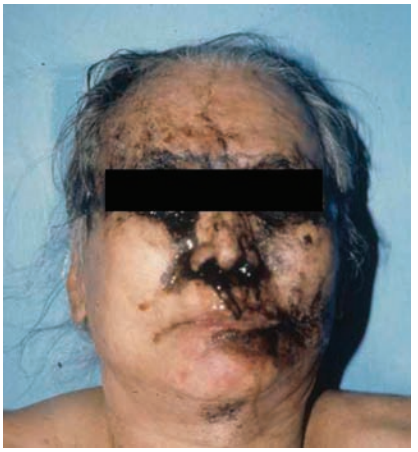

Figure 6.1 Coffee ground hematemesis. Blood that collected in the stomach and was subsequently vomited will have a distinctly brown appearance, caused by the stomach acid. (Photograph courtesy of Dr. David Winston, Pima Forensic Science Center, Tucson, AZ.)

when interpreting an impact pattern. Depending upon the rate of bleeding, the blood may or may not be visibly diluted by mixing with lung secretions or saliva.

***From the gastrointestinal tract or due to liver disease*:** The liver is key to normal blood clotting and anything that diminishes its function makes bleeding more likely. Alcohol abuse is one of the most common causes for cirrhosis of the liver in the United States. Not only does cirrhosis impair liver function and the coagulation process, the scarring that accompanies cirrhosis elevates the pressure in certain blood vessels increasing the risk of rupture. Most of these vessels are along the gastrointestinal tract. Rupture of such dilated vessels in the esophagus (esophageal varices) can result in vomiting of blood that collects in the stomach (hematemesis). This projected blood may appear fresh or may be altered by contact with stomach acid. When altered, it is referred to as "coffee-ground" hematemesis (see Figure 6.1). If blood instead passes through the bowel to the rectum, it may appear as bright red blood (hematochezia), or more likely as a dark brown to black, tarry, foul-smelling material (called melena and caused by the intestinal liquids and contents altering the blood).

Peptic ulcers (ulcers of the stomach or first segment of the small bowel) can also result in rapid gastrointestinal bleeding. Inflammatory processes, cancers, and malformed blood vessels are other causes.

***From a gynecological source*:** Menstrual blood flow can vary widely from woman to woman, but will generally range from less than 30 cc to up to 80 cc of dark red, non-clotting blood over a 3 to 5 day period. The "blood" is mixed microscopically with sloughed endometrium (the lining of the uterus) and mucus. A normal childbirth can be associated with an estimated blood loss of from 500 to 1500 cc. If the placenta is positioned too low in the womb or partially on the cervix (placenta previa) in the third trimester, the woman can suffer sudden profuse vaginal bleeding that can be fatal to both mother and child.[3,9]

***From venous insufficiency*:** Varicose veins that become disrupted from minimal trauma or from chronic medical ulcers can be a source of extensive, even potentially fatal, bleeding. In chronic venous insufficiency, the one-way valves in the leg veins fail. The superficial venous drainage in the legs proceeds not only upward but also inward through perforating veins to the deep venous trunks (the pressure in one draining deep calf vein, the posterior tibial vein, while standing at rest can be approximately 80 mm Hg). Nor-

Figure 6.2 The condition known as venous insufficiency syndrome has the potential to deposit a significant volume of blood into the scene. The patterns may appear "spurt"-like even though they are ejected from veins. (Photograph courtesy of ID Officer Rex Sparks, Des Moines Police Department, Des Moines, IA.)

Figure 6.3 Another example of the patterns produced by venous insufficiency syndrome. Note the serpentine pattern on the vertical surface of the cabinet. These are quite similar to those produced by arterial ejections. (Photograph courtesy of ID Officer Rex Sparks, Des Moines Police Department, Des Moines, IA.)

mally during exercise, the pressures in the deep venous trunks is elevated (in the calf this is as great as 250 mm Hg, and in the thigh, 115 mm Hg), but at the same time the pressure in the more superficial veins drops markedly nearing zero (this effect is referred to as the musculo-venous pump).[6] With chronic venous damage, the elevated pressures in the superficial veins can potentially lead to enormous rapid blood loss. Because of the increased pressure, blood loss of this nature can mimic some of the features of a streaming ejection, such as those expelled from an artery. See Figure 6.2 and Figure 6.3.

***From decomposition*:** Decomposition, in addition to distorting and discoloring the body in ways that mimic antemortem injuries, can result in postmortem liquids that may be confused with antemortem hemorrhage. Decomposition is the combination of autolysis

(the normal breakdown of dead cells) and putrefaction. The putrefactive processes will break down tissues and produce gases that tend to expel liquids from facial mucus membranes. The autolytic processes also break down tissues and blood, making the decomposition fluids dark red to brown. The superficial skin frequently detaches and is filled with this liquid. The appearance can be a rather dramatic process that suggests a markedly bloody face with "blood" flow on the sides of the face. Furthermore, if a limb or the head is in a dependent position, decomposition of that lower congested region can lead to pools of suspicious-looking dark red liquid looking very much like blood dripped into blood or, in concert with putrefactive gases, possibly like projected blood.

Traumatic Pathology

The analyst should be familiar with some aspects of the pathology of injuries in order to understand the forensic pathologist's report. First, it is important to understand that a forensic pathologist describes the injuries assuming the victim is in what is called normal anatomic position. That position is person standing erect, legs together, with his arms by his side, palms facing forward. The injuries are described from the viewpoint of the victim right and left, front and back, etc.

The categories and examples of injuries[17] briefly described in the following, with a few exceptions, are limited to those physical injuries most likely to be of concern to a blood pattern analyst.

Firearm Injuries

A firearm projects more than a bullet from the muzzle. Following the bullet are the rapidly expanding gases created by the burned gunpowder, the residue of the burned gunpowder itself, and any unburned or partially burned gunpowder granules. The bullet and these gunpowder-related products will affect the appearance of the entrance wound.

If the muzzle of the weapon is fully pressed against the skin (a contact wound), then the bullet and all of the gunpowder-related products, including the large volume of gases, are forced into the wound. The gases expand the tissues, typically disrupting the skin and forming an irregular-shaped to stellate (star-shaped), large, gaping-open wound. Reapproximating the wound edges may reveal the original, roughly round, bullet hole as well as a circumferential abrasion pattern (an abrasion is a superficial scrape of the skin). There may also be an abrasion pattern in the shape of the muzzle (a muzzle imprint). Darkening inside the wound edges or on adjacent bone represents gunpowder residues. If the contact wound is over an area where the gases can easily expand inward and sideways, the entrance wound might consist of a simple round hole with a surrounding round abrasion rim, possibly with a muzzle imprint. The inner edges of the wound will show darkening from gunpowder soot and may show a localized pink discoloration of the skeletal muscle caused by carbon monoxide in the gases.

If the muzzle of the weapon is held away from the skin at a distance up to 18 to 24 in., then, in addition to the bullet hole, there is usually a surrounding pattern of gunpowder residue on the skin. This pattern consists of irregular-shaped punctate abrasions around the wound (gunpowder stippling). The closer the muzzle is to the skin, the smaller and more intense this pattern is. These abrasions are caused by unburned or partially burned

gunpowder, as well as any other debris propelled from the barrel, that impact the skin. A careful examination can often reveal occasional embedded particles of the gunpowder-related material in a few of these abrasions. If the muzzle is less than 4 to 6 in. from the skin, there is usually a diffuse, shiny, gray-black discoloration around the wound representing the addition of gunpowder soot being propelled into the skin. The closer the muzzle, the more compact and intense the soot pattern and the less likely one can see the pattern caused by the concomitant gunpowder stippling.

If the muzzle is still further away — 18 to 24 inches, then only a round to oval entrance wound surrounded by a rim of abrasion, created as the bullet enters, is seen.

An exiting bullet tents and tears the skin outward, typically causing a slit-shaped or irregular to stellate-shaped wound. Usually no abrasion rim is seen; although, if the exit wound is shored up against a firm surface or very tight clothing some abrasion may be seen. If the bullet in the body tumbles or breaks up, or if the weapon is a high-powered (high velocity) rifle, the exit wound can be a large gaping defect larger than its corresponding entrance wound. In general, no absolute statements can be made about any correlation between bullet size or type and the relative sizes of entrance and exit wounds.

It is essential to remember that the gunshot wound residue patterns just described are deposited on the first surface encountered. Therefore, a forensic pathologist considers it vital that he or she examine the clothing for soot, stippling, and even searing from the heat of the muzzle blast before offering an opinion about the range of fire. In addition, if a bullet tumbles in flight, breaks up, or ricochets, the characteristics of the entrance wound are often dramatically altered.

Shotguns have some additional wounding characteristics. Because of the large amount of gases produced by a shotgun (seen as well with high-powered rifles or large-caliber handguns), contact shotgun wounds usually show massive disruption of the underlying tissues. A contact shotgun wound to the head is likely to reduce the head to an unrecognizable pulp-like mass.

If the shotgun cartridge load consists of pellets, then at a range of less than 4 to 5 ft from the muzzle, the pellets enter as a single mass creating a round to oval entrance wound. The closer to the upper limit of this distance, the more likely one is to notice scalloping or irregularity along the margins of the wound representing the pellet mass starting to separate. Beyond 4 to 5 ft, the pellets continue to disperse from the central mass creating individual wounds. Eventually, the pellet mass spreads out such that only multiple, roughly round pellet wounds, each with minimal abrasion rims, are produced. Shotgun loads consisting of a single relatively large projectile (rifled slug) often produce large gaping entrance and exit wounds.

A smooth bore shotgun discharge also differs from most other firearms in that the shell contains a component (usually some form of wadding or plastic shot shell cup) between the projectile and the gunpowder charge. With contact wounds and range of fire up to 10 to 12 ft, the wadding can be projected inside the entrance wound. Still further away, the wadding may still impact the surrounding skin, leaving its own abrasion imprint.

Shotgun exit wounds can consist of small separate pellet defects or gaping irregular-shaped defects in the case of masses or clumps of pellet.

Firearm injuries can result in injuries and findings that are not directly along the wound track. For example, a gunshot wound may not involve the orbital region. However, there may be diffuse peri-orbital hemorrhage (appearing as black eyes or "raccoon eyes") resulting from the transmitted force of the blast. It does not represent a separate blunt

injury. A neck, nasal, or oral injury may result in aspirated blood in the lungs that should not be interpreted as a separate injury.

Because of the great variability in the appearance of entry and exit wounds for different firearms, a competent forensic pathologist will often wait until the completion of his or her internal examination (after the pattern of soft tissue and bone injuries are determined) before designating each wound as an entry or exit wound. It behooves the analyst to read the wound descriptions and to review the photographic documentation before accepting the pathologist's opinion.

The variability in gunshot wounds also prevents anyone from making broad predictions as to the form or nature of the blood loss. Considerations must be given to the regions and organs injured by the bullet, as well as the degree of internal hemorrhage.

Sharp Force Injuries

A sharp-edged object that cleaves rather than tears the skin and underlying tissues causes sharp force injuries. Knives are the most commonly encountered sharp force instrument, but many other items such as sharp-edged kitchen utensils, scissors, slotted screwdrivers, and broken glass can be sharp force weapons. Implicit in this observation about other weapons is that there may be an intermediate type injury between sharp force and blunt force (described later) caused by a "dull" sharp instrument or a "sharp" dull instrument (as examples, a "dull" knife or a "sharp" axe).

Skin is a relatively elastic surface that is stretched along specific lines of tension. Therefore, sharp force wound edges have to be re-approximated to provide an estimate of the true wound size and shape (and through this, possible dimensions of the weapon). Typically, there is no abrasion rim surrounding the wound unless there is a defect on the blade, a knife is thrust to the hilt, or a weapon of intermediate sharpness is used.

If the depth of a sharp force wound is greater than its largest surface dimension, it is referred to as a stab wound. If the skin wound is longer than it is deep, then it is referred to as an incised wound (that is, a slashing or cutting wound). Some sharp force wounds may have both a stab (thrusting) component as well as an incised component as the thrusted weapon is also pulled parallel to the skin surface. The depth of the wound track may be reported as a range. Descriptions of injuries in the anatomic position cannot reveal if the victim was inhaling or exhaling, twisted, or bent over. Additionally, the compressibility of tissues should be considered. These are all factors that may influence the pathologist's ability to accurately estimate the true wound depth or even the true direction of the wound path.

The wound edges may give additional information about the weapon, such as squaring of one wound angle consistent with a single-edged knife, or waviness of the wound edge or surrounding skin suggesting a serrated blade. Defects or irregularities in the cutting surface may be reproduced in the wound edges. The adjacent skin can show evidence of multiple parallel superficial wounds (sawing) or linear abrasions (in suicides interpreted as hesitation marks).

Wounds on the hands or arms may be positioned such that they suggest that the victim was defending himself or trying to ward off the attack. The forensic pathologist may categorize these injuries as defensive wounds.

Once again, the variability of internal trauma and internal bleeding caused by sharp force injuries should make one very hesitant about making broad predictions concerning the rapidity, volume, or character of external blood loss based solely on the type of wound.

Blunt Injuries

A relatively broad-based force that tears and crushes tissues produces blunt injuries. These are the type of injuries one would see in a victim attacked with a bat, beaten with hands or feet, or resulting from a fall or motor vehicle collision. Externally, these injuries consist of lacerations, contusions, and abrasions.

Abrasions are scrapes or scratches of the most superficial layers of the skin. An abrasion can vary from a barely perceptible pink-tan mark to a dark red-brown discoloration. Postmortem drying and the draining of blood away from the skin cause initially pale abrasions to appear much darker and more prominent. In a victim who survives, the leakage of a small amount of blood and cellular fluids from the deeper skin can form a dried crust within a day (a scab).

Contusions are bruises. Bruising occurs when an applied force ruptures blood vessels, and the blood, with the impetus of circulatory pressure, extends into the surrounding tissues. An acute bruise can appear as a wide color spectrum besides the typical "black and blue" depending upon the depth, size, and density of the hemorrhage. Over several weeks as a bruise is repaired and reabsorbed, it undergoes color changes to green-yellow and eventually brown. If the age of a bruise is both relevant and in doubt, great care should be exercised in color-based examination alone. Benefit can be gained by microscopic examination of the bruised tissues by a forensic pathologist. It is very easy to be wrong based upon gross appearances.

Lacerations are tears. Lacerations occur when a blunt force shears or tears the skin and underlying tissues. A laceration is more likely to have irregular or uneven edges with abrasion along the margins. The subcutaneous tissues beneath the skin at a laceration often are undermined (producing a cul-de-sac-like region of separation in the soft tissue). Within the laceration's edges or in the undermined regions, bridges of the soft tissues are found. These tissue bridges represent intact stronger bands adjacent to weaker torn tissue. When the wound is gently pulled apart or lifted, string-like bands of tissue form a bridge from the skin edge to the deeper tissues.

Multiple factors can influence the extent of bleeding from a blunt injury. A laceration to a region with a large vascular bed (the scalp and face) will cause more rapid and voluminous blood loss than a less vascular region (the sole of the foot). Limb injuries expected to result in copious bleeding that are distal to a disrupted central vessel may produce minimal bleeding. Hypotension (low blood pressure) from internal injuries may limit bleeding from even severe external injuries. Finally, the forensic pathologist may determine that some of the injuries are postmortem and resulted in minimal or no bleeding at all. One should be hesitant to make overly specific predictions about bleeding and would be wise never to make any predictions without the full medical or autopsy reports.

The shape and patterns of injuries can provide information about their source. A crescent-shaped laceration may suggest a pipe or a hammer. For instance, several evenly spaced pairs of uniform rectangular-shaped lacerations may indicate the prong end of a hammer. Repetitive abrasion and contusion patterns in the skin can be suggestive of footwear injuries from stomping. As with pattern transfers in blood, there is no limit to the nature of pattern injuries. The forensic pathologist will be very interested in reviewing any pattern transfers at the scene. This may aid the pathologist in understanding the patterned injuries and recognizing potential sources of the pattern. As with blood transfer patterns, the detail from these pattern injuries usually provides only class characteristics. However,

occasionally individual characteristics allow for a match or near-match of the patterned injury to a specific weapon or object (provided one-to-one photographic documentation could be provided to the criminalist).

Under the correct circumstances, a broad-based blunt force may leave little or no external injuries while producing fatal internal results in the head or torso. Even a fracture to the femur (thigh bone) can be associated with over 1500 ml of local internal bleeding that can result in shock and death.

The head can be lethally injured with minimal external findings. A skull fracture can be associated with bleeding and contusions within internal membranes and in the brain. Contusions to the brain can occur without skull fractures or even discernible external blunt injuries to the scalp. When a moving head strikes a stationary firm object and the force from the impact is transmitted through the head, contusions to the brain are often seen on the opposite side (contrecoup contusions). Moreover, impacts to a head at rest without a skull fracture can occasionally produce contusions on the same side (coup contusions). These latter contusions occur with an intact skull. They should be distinguished from contusions found underneath skull fractures (fracture contusions).

Of the several protective membranes surrounding the brain, the thickest and outermost layer is the dura mater. There are thin veins in the upper midline region of the brain that bridge across from the dura to the brain which can be sheared from a blunt impact. The bleeding from these veins (subdural hematoma) can collect slowly over hours and even days before causing symptoms. Bleeding from arteries intimately associated with the skull, typically resulting from a skull fracture, can produce a much more rapid collection of blood between the dura and the skull (epidural hematoma).

The Forensic Pathologist as a Resource

A forensic pathologist is a medical subspecialist who has training and experience in examining and documenting unusual or unnatural deaths, particularly deaths due to trauma. Basic issues or questions posed to the forensic pathologist might include the following:

1. Time of death? The observations at the scene of rigor mortis and livor mortis can form a rough basis for time of death. Rigor mortis is the stiffness (not contraction) that forms in all of the skeletal muscles after death. It is related to acidosis, which causes muscle cell contractile proteins to bind. Rigor mortis starts at about 1/2 to 1 h after death and reaches a maximum by or before 12 h. After about 24 h, rigor mortis begins to dissipate as decomposition changes emerge. Livor mortis is the postmortem red to purple-blue settling of blood to the dependent portions of the body. Livor mortis is usually seen within a few hours after death and increases in intensity over the next few hours. Pressing the lividity during this time will reveal blanching. Turning the body over during the first few hours is like turning the sands in an hourglass. The lividity will redistribute to the new gravity-driven dependent portions of the body. However, at about 8 to 12 h, the lividity becomes fixed. The drop in body temperature congeals the blood in the smallest vessels. This and the extravasation of blood into the tissues prevent any further blanching or shifting of the blood.

   There can be a wide range of variation to the onset and development of rigor mortis and lividity. The general "rules of thumb" noted previously should remain

just that. Many factors, including obesity, muscle mass wasting, antemortem anemia, and strenuous exertion, can affect the onset and extent of both.

Other postmortem changes such as declining core body temperature or the electrolyte content of vitreous humor can add information but are not generally accepted individually as reliable indices. With these tools, the forensic pathologist can provide a several-hour time range that may be useful to the investigator.

2. Is there an injury at all? The forensic pathologist can determine if antemortem injuries are present, or if postmortem changes and/or medical conditions are responsible for the apparent "bloodshed." Especially in decomposed remains, distinguishing antemortem from postmortem changes can be challenging. In some cases, bruises and lividity can be surprisingly hard to distinguish. The elderly are more prone to bleeding after incidental minor trauma that can nevertheless appear dramatic. The forensic pathologist can determine if these are trivial or significant injuries.
3. What is the source and extent of the bloodshed? The forensic pathologist can document the nature and extent of injuries that could account for the observed blood patterns. He may be able to distinguish features or injuries that limit the actions of a victim (for example, a gunshot wound to the thoracic spine rendering the victim unable to walk), or suggest the sequence of events at the blood pattern scene. Documentation of massive internal bleeding may explain the paucity of blood at a scene (instead of suggesting that there is another, yet undiscovered, crime scene). Documentation of blood in the airways may explain an otherwise confusing spatter pattern. The forensic pathologist can confirm the possible mixing of cerebrospinal fluid and blood in a head wound that would explain diluted stains at a scene. The forensic pathologist will certainly document damage to the larger vessels and may offer functional information on injuries to smaller vessels (taking into account that small, relatively minor, arteries can be responsible for significant bleeding), all of which helps explain patterns at the crime scene. An incompletely incised artery may explain an arterial spurt, while a fully transected artery that retracted back into the deep muscle may explain a more non-specific projected (gush) pattern.
4. Are all the injuries antemortem? The forensic pathologist should be able to determine if all of the wounds are associated with hemorrhage in the tissues. A lack of tissue hemorrhage could represent further injury after death.
5. Are the injuries hospital-acquired? The forensic pathologist can bridge the gap between the investigator and the health care providers. A review of the medical records can provide vital information to distinguish inflicted injury from that associated with therapy. As an example, bleeding that mimics contusions can surround venipunctures. Another common example is the injury produced by the rib spreaders used to open the chest for cardiac massage in emergency departments. This injury has been known to be erroneously attributed to various mechanisms of injury including gunshot.

The forensic pathologist should be a resource that every blood pattern analyst uses routinely. Moreover, as much as anything else, the forensic pathologist's job is to be able to explain his or her findings in basic understandable terms. If he or she cannot, get a second opinion.

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Determining Motion and Directionality

7

Establishing the motion involved in bloodshed events and specifically identifying directionality in blood droplets allows the analyst to understand more fully the specific events that occurred during an incident. The nature of this motion is threefold:

- General direction of events — Where did the event begin? Where did it end?
- Droplet directionality — Identifying the direction from which a given spatter droplet struck a target.
- Recognition of blood trail or stain motion — In which direction does a specific trail or stain lead?

General Sequence of Events

This first issue is one that may seem self-evident; however, it is often misunderstood or misinterpreted. A general rule can be applied in bloodstain pattern analysis that is reciprocal to a rule found in arson investigation. In any arson the investigator looks for the point where the fire caused the greatest damage. Typically, the point with the greatest damage is the point where the fire burned longest, which is likely to be the origin. In bloodstained scenes we apply this approach in reverse. The location where we find the greatest bloodshed is most likely the ending point of the incident. The location where we find the least blood (spatter and drips) is likely at or near the point where the bloodshed started.

This rule for bloodstained scenes exists for two reasons. As the attacker inflicts injuries, the level of bleeding is likely to increase as greater damage and breaching of the circulatory system occurs. The resulting damage and shock decrease the victim's ability to escape and retain mobility. The end effect is an increase in bleeding volume at any given location in the latter stages of the event as compared to the earlier stages. It is not an absolute rule, nor do we suggest that it is. However, applied to most scenes it will guide the analyst. Amazingly, analysts often overlook the second reason for this effect. Once breached, should death follow, nothing but body position prevents the victim from passively bleeding out the contents of the circulatory system. Once again this rule should not to be taken as absolute, yet as we move through a given scene, those locations with only limited spatter or stains will likely lead to areas of greater spatter or stains. As the victim sustains different wounds the patterns may change, but the increase in bleeding should be apparent.

For example, if the first blows of an attack create a small laceration, we may see evidence of drops falling because of venous bleeding. We may even find minor spatter on a wall or surrounding surface close to where the victim received the blow.

As the victim retreats to another area, the venous bleeding of the laceration continues. At the second location, the attacker strikes the victim again. Blood is present on the body from the first wound; thus, the blow itself creates heavier impact spatter. These blows create a widening of the wound, which in turn increases the venous blood flow. Blood may be accumulating in the clothing to the point it reaches a saturation level and begins dripping or producing significant contact patterns. Now attempting to defend against the blows

rather than escape them, or perhaps dazed as a result of the blows, the progress of the victim may begin to slow. The volume of blood lost at any point increases as the victim remains in that location longer. Throughout the events, the victim's hands and clothing become stained. In turn, these objects stain walls and surrounding items. The more blood, the more soaked the items; the more soaked the items, the more staining present. It is by viewing the stains in this fashion that we may discern a general flow of the overall incident and the events that define it.

The obvious exception to this rule is a situation in which the body is moved to a secondary scene after bleeding out in the primary. Here the absence of blood is significant and will become an alternative indication for sequencing actions.

Droplet Directionality

As discussed in Chapter 5, blood impacting a surface acts in a relatively defined fashion. Based upon this impact, one thing usually evident to the analyst is the directionality of a given droplet. The exceptions to determining directionality are carpets and other highly absorbent or irregular surfaces.

As the liquid droplet contacts a surface, the droplet begins collapsing. Inertia keeps the mass of the droplet moving along the same path it was traveling before its encounter with the target. The blood present in the droplet flows outward to the edges of the stain during the collapse, creating either an elliptical or circular stain depending upon the angle of impact. Figure 7.1 details how this motion occurs. Whatever the shape, the resulting stain (unless impacting at 90°) will have both a major and minor axis. The major axis (longest axis) is always aligned with the path of the droplet.

The major axis of this ellipse begins our definition of the droplet's directionality. This axis defines a line with two possible droplet directions (see Figure 7.2). In viewing the stain, the analyst must seek information to eliminate one of the two directions. Satellite stains, scallops, or spines provide the analyst a means for making this elimination and identifying the direction of travel.

As the discussion of dispersion in Chapter 5 explained, when the droplet collapses a blossom effect begins. The exact nature of this blossom is defined both by the angle of impact and the nature of the target surface. As this blossom develops, surface tension of the liquid pulls the blood into distinct protuberances in the leading edge of the blossom structure. These formations in many instances break from the blossom structure, creating satellite stains. Whether these protuberances break completely free or simply form spines or scallops, their presence in relationship to the long axis of the stain helps define the motion of the droplet at impact.

The path these spines and satellite droplets follow is defined by the redirection of the blood as it impacts. In instances of 70° to 90° impacts (the more circular stains), spines and satellite stains may be evident all around the parent stain (see Figure 7.3 and Figure 7.4). As this angle decreases, however, one side will show greater evidence of both. By considering the long axis of the stain in combination with the highest concentration of satellite stains or spines on one side, the analyst can identify a general direction of travel for the droplet.

A measure of caution is always in order when considering 70° through 90° impacts. Surface disturbances or angles present in the target may lead to slight deviations in the outflow of blood. This can affect the resulting spines or satellite stains. Such deviations, combined

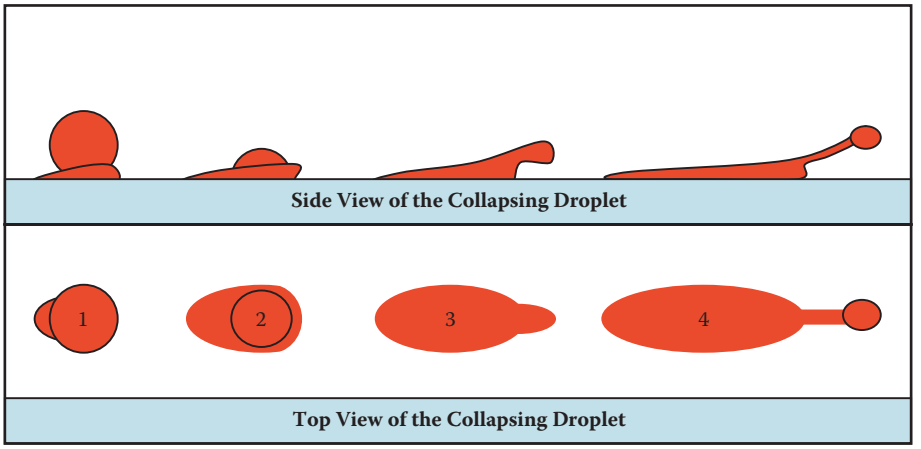


Figure 7.1 A graphic of a collapsing droplet impacting at an acute angle. This demonstrates how the long axis of the ellipse develops and is oriented along the path of travel.

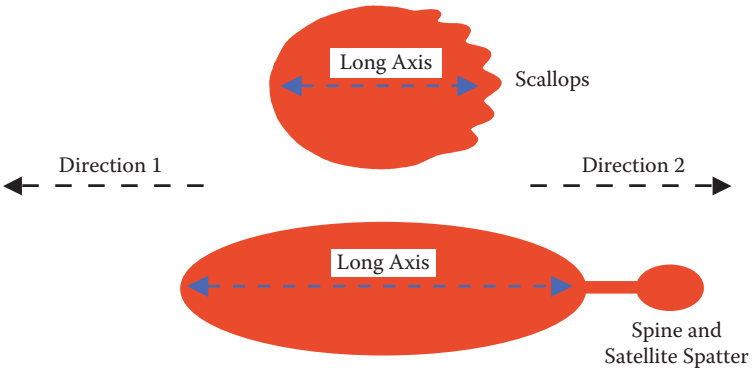


Figure 7.2 The presence of spines, scallops, spatter, or tails all help the analyst identify the path the droplet was traveling at impact. These structures are found opposite (or at least concentrated opposite) the side of the stain that impacted first.

with our ability to identify only a general direction in these instances, make the trustworthiness of the directionality much lower than that found in elliptically shaped stains.

Fortunately, as the impact angle decreases (e.g., moves toward a 10° impact) clarity of this direction increases. In droplet impacts between 40° and 70°, the nature of the outflow of blood is likely to create a number of spines and/or satellite spatter oriented to one

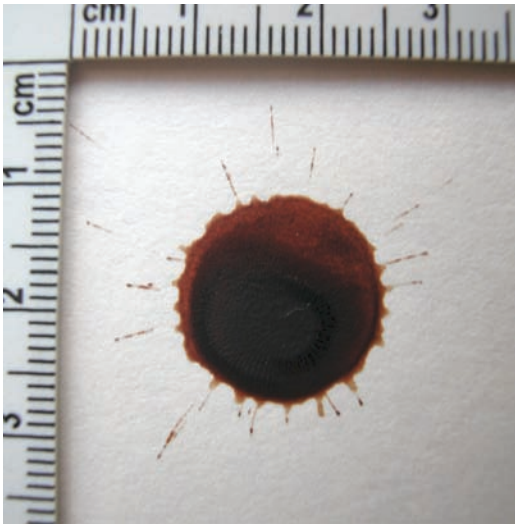


Figure 7.3 A 90° impact. Evident are small scallops, which appear around the entire periphery of the stain.

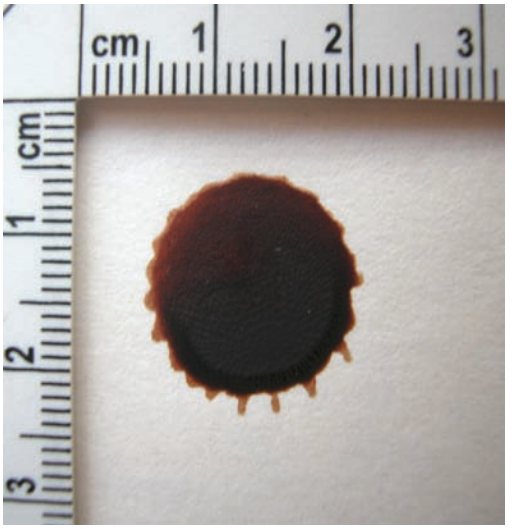


Figure 7.4 A 70° impact. Note the greater concentration of large scallops on one side of the stain. They are opposite the droplet's origin and point in the general direction the droplet was traveling. Directionality in circular shaped stains is not as clear as in elliptical stains because the spines are not concentrated along a single vector.

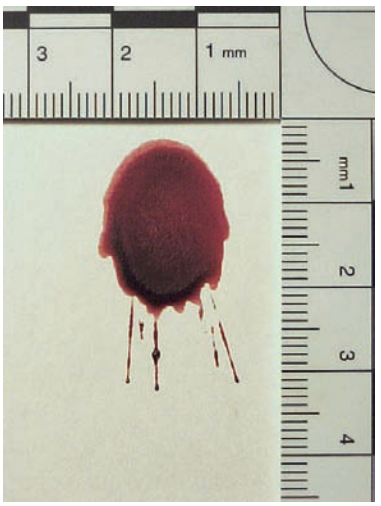


Figure 7.5 A 50° impact. In this instance, the scallops have spawned significant tadpole tails. Once again, these tails point generally in the direction the droplet was traveling. Although directionality is not as specific as when we find a more elliptical stain, the analyst can still effectively define the droplet's directionality.

side of the stain. The position and direction evident in the spines and satellite stains defines a relatively accurate path of travel (see Figure 7.5).

In impacts below 40°, the resulting stains are much more elliptical. In such instances, the outflow of blood travels almost exclusively along the leading edge of the collapsing droplet (much as in our drawing in Figure 7.1). Such an impact is likely to create a single spine and satellite stain (see Figure 7.6). Consideration of where this spine/tail exits the parent stain in combination with the major axis of the parent forms a very distinct alignment for the directionality.

In these elliptical stains, the direction of travel for the satellite spatter often matches that of the parent stain. However, minor redirection of the satellite can occur resulting in a spine or tail offset to the actual direction of travel. For this reason, alignment along the major/long axis of the parent remains the best indicator of directionality. If the analyst attempts to use the full length of the tail and satellite stain in this alignment, it may throw off the directional angle (see Figure 7.7).

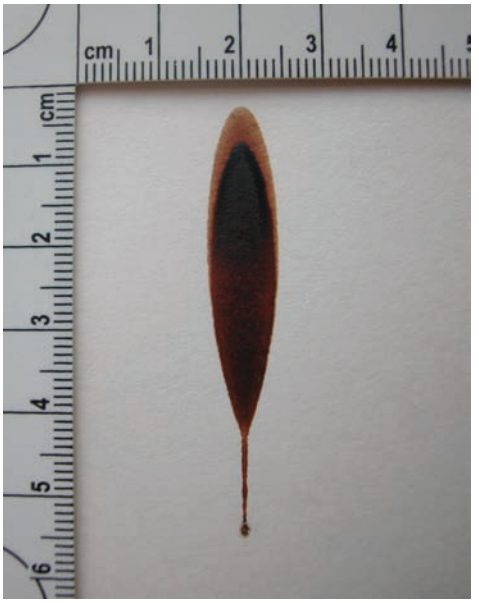


Figure 7.6 A 10° impact. This stain has a single tail and satellite. In combination with the long axis of the elliptical stain, it provides a very specific indication of the droplet's path of travel.

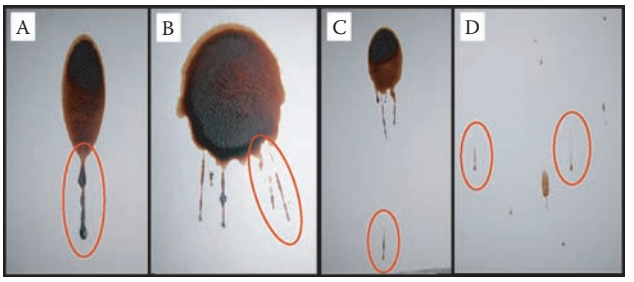
Figure 7.7 The spine associated with elliptical stains will not always align exactly with the directional angle. The red line divides the major axis of the stain and indicates its directionality. Note that the spine shows redirection slightly to the left.

If you will recall our discussion of parent and satellite stains in Chapter 2, we made it clear that it is important to differentiate between the two. (The reader may wish to refer to Figure 2.19.) Both the parent and satellite stains may have a tail. While the parent tail points in the direction of the droplet's travel, the satellite tail points back to the parent drop. If the analyst were to confuse a satellite for a parent, this would obviously confuse the investigative findings. In practice, it is usually quite easy to identify a parent and satellite relationship, as their tails often align with one another.

Satellite stains can occur in the scene in various fashions, several of which will be detached from their parent (see Figure 7.8). These include:

- Attached to the parent stain
- Semi-detached from the parent stain
- Detached but in proximity to the parent stain
- Detached and disassociated from the parent stain

In circumstances where the satellite is attached, semi-attached, or detached and in direct proximity, the correlation of parent to satellite is relatively easy. However, in instances of acute angle impacts detached satellites can end up some distance away from the parent stains; however, the shape of these satellites is dissimilar to the shape of a parent stain. This makes them easy to distinguish. Satellite stains have a very distinct tadpole look to them (see Figure 7.9), far different from the elliptical nature of a parent stain. If the analyst is properly trained and has spent any amount of time looking at spatter patterns, it would be difficult to mistake them as parent stains.



Satellite spatter can be found:
A – Attached to the parent stain
B – Semi-detached from the parent stain
C – Detached and in proximity to the parent stain
D – Detached and disassociated from the parent stain

Figure 7.8 Satellite spatter can appear in many forms. It can be attached, semi-detached, detached and in proximity, or totally disassociated from its parent. In the latter case, it is imperative that the analyst recognize the difference between satellites and parent stains.

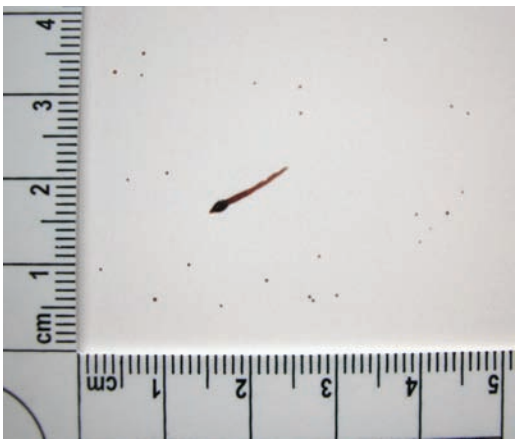


Figure 7.9 A disassociated satellite stain. These stains have a very distinct tadpole look to them, which is different from the elliptical shape seen in parent stains.

In practice, it is simple for the analyst to visualize the directionality of any given droplet. The analyst simply draws a line down the center of the long axis of the stain (no matter what its shape), looking for and then using the presence of any tails, scallops, or satellites to understand the direction. The more elliptical the stain, the more defined the directionality (see Figure 7.10).

If you recall our discussion of the effect of target surface on the collapsing droplet from Chapter 5 (refer to Figure 5.10), it should be evident that a rough target can impair our ability to read a stain. Yet a rough or irregular surface alone, particularly in instances of the more elliptical stains, does not mean we cannot define directionality. Consider a worst case, such as a stain found on asphalt. The resulting stain may well be disturbed (when compared to one impacting a smooth surface), but the directionality may still be evident. The irregular outflow of blood in the parent stain during the displacement and dispersion phases usually does not mask the directionality entirely (see Figure 7.11).

Given our discussion, we can say the following regarding directionality:

- The more elliptical the stain, the more accurate the definition of directionality.
- Less elliptical stains demand a cautionary approach. Stains with impact angles greater than 70° are extremely difficult to evaluate.
- The smoother the target, the less likely irregularities will occur which might mask the directionality.
- Directionality may be evident on rough surfaces, but a cautionary approach is required.

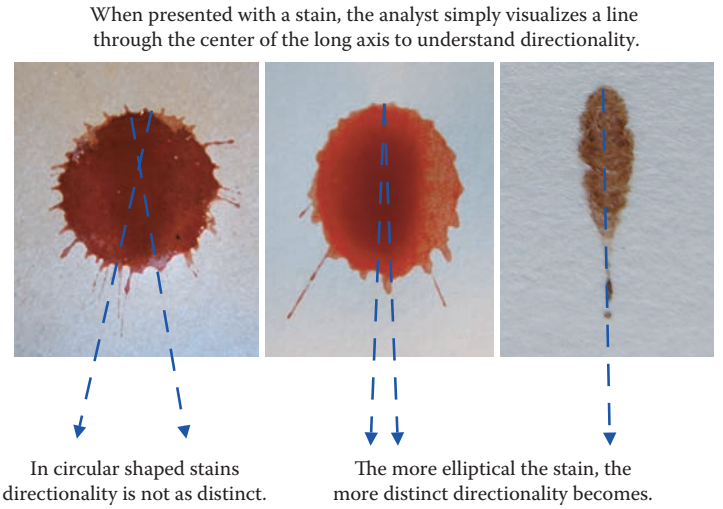


Figure 7.10 To visualize or demonstrate directionality in a droplet the analyst simply draws a line down the center (the long axis) of the stain, splitting it into two equal parts. The problem becomes defining where this line belongs in the more circular stains. Finding the "center" of the stain in these instances presents a range of possibility. The more elliptical the stain, the more defined the directionality.

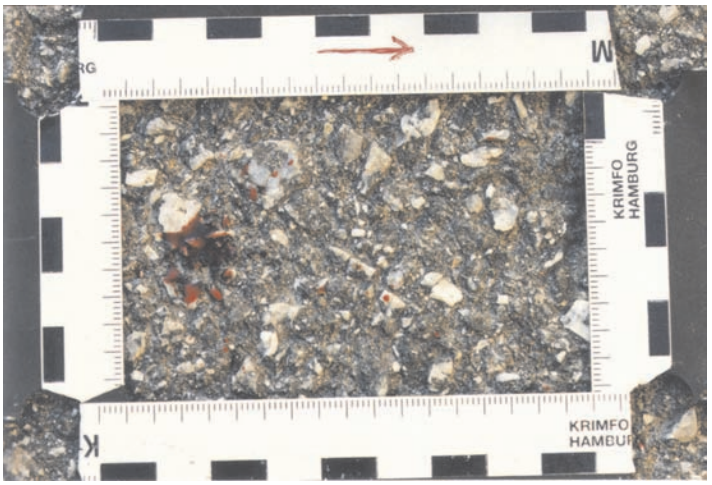


Figure 7.11 Even in cases of significantly rough surfaces such as asphalt, directionality is not always a lost cause. This photograph shows small satellite spatter deposited to the right side of the parent stain, indicating directionality from left to right.

A final word of concern is in order for determining the directionality of a droplet. Directionality in relation to the source of the blood, although quite obvious, is not a certain conclusion for two reasons. First, when we speak of directionality we are discussing only the path a droplet was traveling at the time it impacted a given target. It is possible to encounter ricochet situations in which a volume of blood strikes an interim target. This causes the blood to change its original path, impacting the target as evidenced by its final position. Ricochets are possible and must be considered in the overall analysis. Second, if

the target itself is capable of motion at the time of bloodshed, consider the directionality and the angle of impact cautiously. Obviously, motion of a target makes it difficult at best to establish directionality in any fashion. If one cannot establish the target's position at the moment the droplet strikes, a single stain by itself may tell the analyst little. When examining such items, the presence of radiating patterns will make this concern moot. Although multiple spatters could fall down onto a moving target, their resulting directional angles would be parallel, in line with movement. It is the motion of the target that produces this mimic effect, so each directional angle would be generally parallel to the next. If the individual spatters on the object are radiating outward as typical impact patterns do, the directional angles of the spatters must be a function of their flight paths and not from the motion of the target.

Recently a term was introduced associated with directionality. "Reverse directionality" has been used by some authors to explain the presence of random directionality of satellites seen in splash patterns.[1] The authors find this term extremely inappropriate for one simple reason. Directionality, the path a particular drop was moving at the time of impact, is defined by the resulting shape of the stain. This shape is ordained by physical laws that do not change; the motion of the droplet when it strikes a target will produce the same effect each and every time. The shape of a parent stain tells us one thing; the shape of a satellite stain tells us another. We also recognize that if a droplet falls to a surface that is in motion, the resulting shape may mimic an acute angle impact. These are the rules and they are always in play. The term "reverse directionality" suggests to the layman that the droplet was going in a direction opposite that described by its shape. The resulting inference has the potential to be used to suggest that the most basic issue in bloodstain pattern analysis is not valid. The authors have already encountered unqualified analysts who made exactly such a claim in court. In one instance, an analyst attempted to explain that the directionality of impact spatter was opposite that indicated by the shape because of "reverse directionality." The fact that the analyst was using a term associated with a splash in the context of an impact spatter pattern was problematic, but the implication of the analyst defied a basic understanding of droplet behavior or resulted from his inability to recognize a parent from a satellite. There is no instance of which we are aware in which a stain's shape (applying the rules as described) reflects a direction of motion opposite that as described. There simply is no "reverse directionality."

As intended by the original authors, "reverse directionality" describes the odd and random way spatter spines and satellites eject out from the primary stain. It was discussed in relation to a "splash pattern," but the effect can be observed in any large volume ejection that is directed relatively perpendicular to a target. This area has never been studied in detail, but it is a highly complex event (see Figure 7.12). The resulting stains surrounding the primary stain include satellites ejected from the primary stain itself (marked as A in Figure 7.12), spatter stains and their satellites ejected out from the pattern (marked as B in Figure 7.12), spines ejected out from the primary stain (marked as C in Figure 7.12), and odd linear patterns (marked as D in Figure 7.12). It is believed the latter characteristic results from small droplets that are traveling at extremely acute angles to the target surface. All of these actions are occurring nearly simultaneous to the impact of the volume; they may well collide in some instances, there may be deflections of some sort, but they do not reverse direction as a function of these interactions.

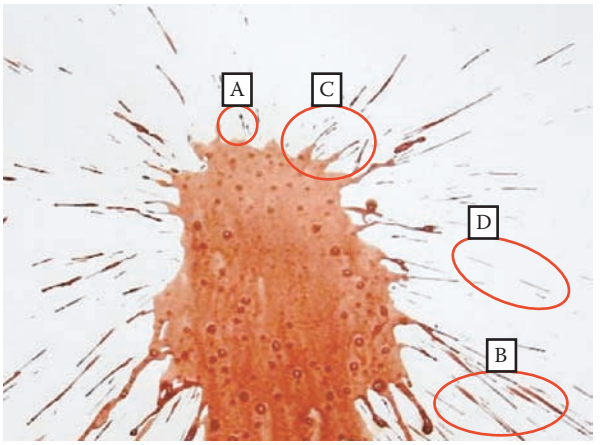


Figure 7.12 When a large volume of blood impacts a surface, the interaction creates several interesting characteristics related to directionality. These include: (A) detached satellite stains ejected from the primary stain, (B) spatter ejected from the primary stain, (C) spines emanating from the primary stain, and (D) long intermittent linear stains. There is no doubt that some collisions and deflections occur in such a complex event, but this in no way alters our understanding of directionality.

Recognizing Blood Trail Motion

Our previous consideration of stain directionality leads us to a major consideration: that of blood trails. As individuals become injured and then move, or bloody items are moved within a scene, blood trails are likely to occur.

The drops resulting from these dripping actions strike the surrounding floors and surfaces. As they break free, they are moving with the same momentum and in the same direction as the item from which they fell. The combination of gravity and this momentum causes the drops to impact the ground at varying angles, but all generally greater than 50°. The resulting stains in the blood trail show evidence of this angle and its direction (see Figure 7.13). This directionality, in consideration of the repetitive nature of the blood trail, allows the investigator to determine which direction the trail leads. Figure 7.14 is an example of a typical blood trail.

Figure 7.15 depicts a blood trail on a coarse irregular surface; nevertheless, directionality is still evident in the resulting bloodstains. Figure 7.16 and Figure 7.17 depict individual stains with elliptical shapes. Although anything but symmetrical, it is very apparent the direction the droplet was moving at impact. Figure 7.18 depicts a stain found further along the blood trail. This stain is far more circular and given the stain by itself, no directionality would be evident. Only by considering stains along the entire length of the blood trail can one usually establish the direction of travel.

The individual stains also assist in establishing the pace or speed of the item creating the blood trail. The more elliptical stains (refer to Figure 7.13) indicate a greater forward velocity than those that are circular. The shapes in Figure 7.16 and Figure 7.17 show evident forward momentum, while the shape in Figure 7.18 indicates less forward movement. The faster the motion of the person or object from which the blood drips, the more momentum the falling droplet has. This forward momentum translates into a more acute angle of impact, which results in more elliptical stains within the pattern. Thus, a series of different

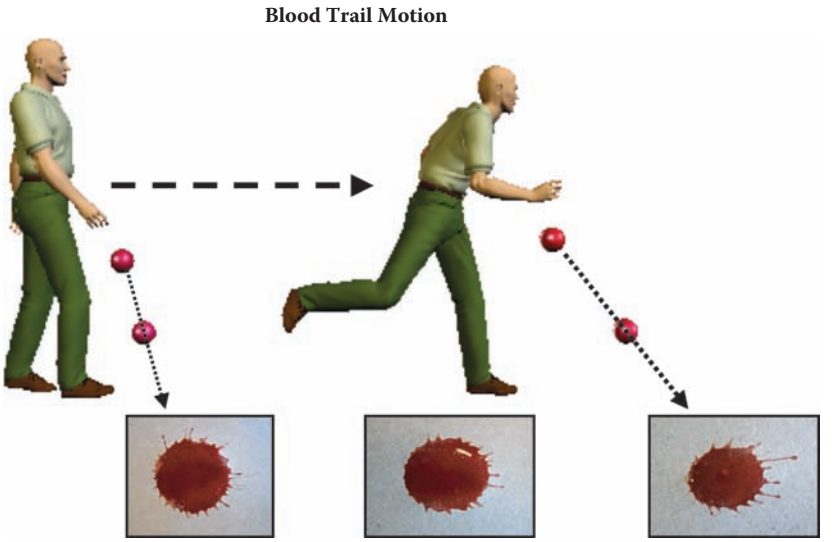


Figure 7.13 Blood trail motion is defined by considering the directionality of the individual drops across the entire pattern.

Figure 7.14 A typical blood trail pattern. Although the photograph does not allow us to see the close-up detail of spines and scallops, on closer examination this information is evident.

shaped stains at different points along the trail may well indicate a change in the speed at which the item is moving.

The presence of a drip pattern at any point along the blood trail would also assist in this regard, indicating that the item dripping the blood had become stationary for some period. When evaluating a drip trail, remember that it takes nothing more than a swing of the dripping item to create a cast-off event in any given direction. It is not uncommon to encounter a drip trail that demonstrates a primary direction of motion along the overall pattern, but with some of the drops showing scallops, tails, and satellites in the opposite direction. This is not "reverse directionality," it is simply the result of a swing of the dripping object. For drip trails, it is the overall characteristics of the pattern that will define the direction of motion, not those of a single stain.

Figure 7.15 A blood trail pattern on concrete. The photo tents will allow us to orient the location of specific stains and their shapes to the pattern as a whole.

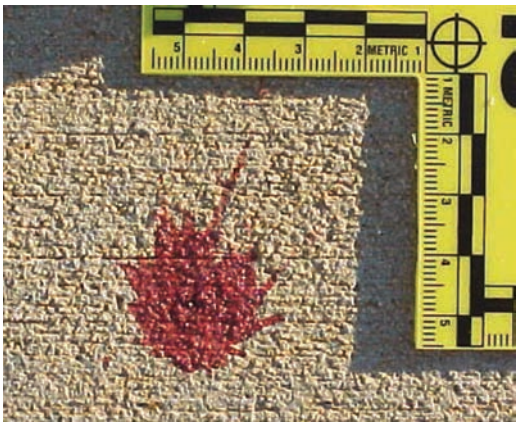


Figure 7.16 Stain #2 from the previous pattern (Figure 7.15), an elliptical stain with evident directionality. The directionality evident in the pattern in Figure 7.15 is away from the camera.

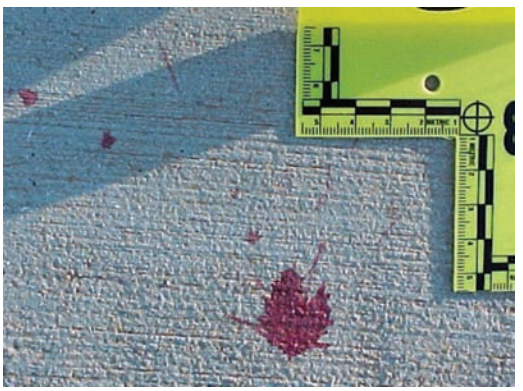


Figure 7.17 Stain #3 from the pattern in Figure 7.15. This stain is significantly irregular in its shape. Satellite spatter are still evident to identify directionality. Note the satellite spine approximately 15 mm to the left of the photo tent.

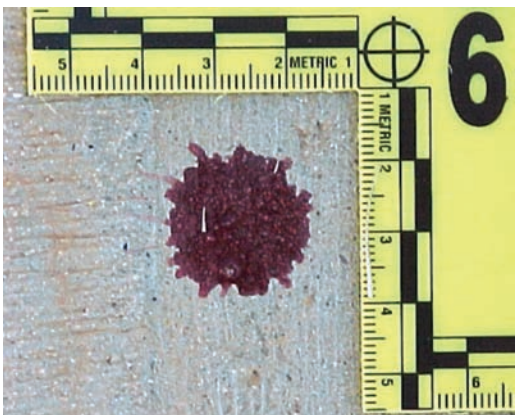


Figure 7.18 A very circular stain from the pattern in Figure 7.15. Taken as a single stain, the shape is not helpful, but considering the shapes evident along the whole pattern, we can still be confident of the direction of travel. The change in shape does indicate a change in the speed of the item dripping the blood. The more circular stains indicate the item was moving slower at this point than when dripping in Figure 7.16 and Figure 7.17.

Figure 7.19 A large volume wipe pattern on a floor. The displacement of blood allows us to know in which direction the motion of the wipe occurred (for the largest stain it is toward the bottom of the picture).

Figure 7.20 A spatter pattern that was wiped through after deposit. The wiping and displacement of the liquid blood leaves evidence of right to left motion by whatever caused the wipe.

Determining Motion from Wipes and Swipes

Another consideration for determining motion in the scene is stains that show evidence of a specific action of some nature. We defined wipes and swipes previously in Chapter 2 and Chapter 3. Both play a prominent role in defining motion.

As items become bloodied and stains are created, events at the scene may still be proceeding. These stains often become disturbed by other events, thus detailing specific motions for later evaluation. This motion is most obvious in instances of wipes; that is, when we have a preexisting stain. Figure 7.19 shows a large volume wipe present on a kitchen floor. Another often-encountered wipe example is when a blow creates a spatter pattern and the spatter is then disturbed. The spatter had specific boundaries to begin with. As the blood within the stain boundary is wiped through, it is moved in the same direction as the item disturbing it. In these instances, the nature or direction of the motion that disturbed the pattern is usually evident (see Figure 7.20).

In a situation involving a swipe, the direction may not be as evident. Depending upon how the bloody object comes in contact with the target, the leading and trailing boundaries for the stain may be similar or radically different. If the edges are similar, there may be no functional method to establish the specific direction in which the swipe occurred.

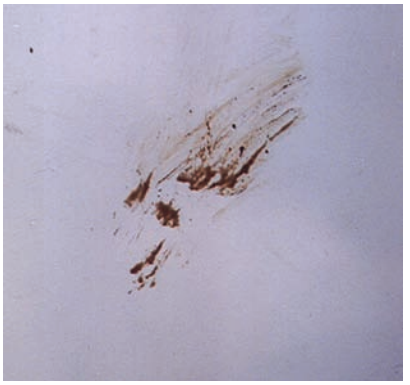


Figure 7.21 A swipe pattern on a plate glass window. The linear features in the stain that run diagonally up and to the right, as well as the thinning of the blood volume in this direction, indicate the motion of the swipe as up and to the right.

Generally, in a swipe, we seek to locate evidence of a thinning of the stain's appearance or color to help define the motion. As the blood volume is deposited against the target, the volume available to be swiped and smeared against the target decreases. The appearance of the final portion of the swipe often demonstrates this "thinning" characteristic as a result.

In addition to the thinning of the color and consistency of the stain, we may also see trailers leading away from the main stain. These linear features result as the bloody object loses contact with the target surface (see Figure 7.21). Such trailers are commonly referred to as "feathering" of the stain. Unfortunately, if the leading and trailing boundaries share similar characteristics, they are likely to share this feathering characteristic. When feathering is evident in both boundaries of the stain, one must be cautious in the evaluation. This is particularly true in instances of hair swipes. The presence of feathering on a single side of the stain is usually a significant characteristic that allows for easy identification of the motion involved.

In the past, analysts have claimed that "feathering" is not a functional means of evaluating directionality of a wipe or swipe. This belief may well be based on the possible presence of feathering in both boundaries. These authors offer two alternative methods for evaluating direction of the swipe and wipe, including displacement of the volume of blood and the evaluation of the "gritty" nature of the blood based on drying characteristics.[2]

As previously discussed with regard to wipes, displacement is clearly a functional method of determining direction, if it is present. Displacement, however, can suffer the same limitation as feathering with regard to defining directionality. Depending upon the means of application of the swiping or wiping object, displacement of the blood can occur in both directions. The gritty nature of blood is not a characteristic we feel is currently functional for defining motion in a stain.

In 2002, Gardner conducted a study of directionality in swipe patterns. A primary conclusion of the study was that three characteristics routinely appeared on the departure side of the swipe mark. These included feathered edges, striations in the body of the stain, and diminished volume.[3] Based on this effort and our experience, we feel comfortable stating that feathering must be considered in relation to all other characteristics of the stain. When the stain is considered in a holistic fashion, feathering is a significant characteristic for defining direction of movement of the swiping object.

Figure 7.22 A repetitive pattern transfer resulting from a shoe stepping into the large pool of blood at the top of the photograph. The wearer then stepped backward.

It is in this fashion that wipes and swipes assist in defining motion and may help to identify the nature of the item that was in motion.

Repetitive Pattern Transfers

Repetitive transfer patterns can also define motion in the scene. A repetitive transfer pattern occurs when an item becomes bloodied and then comes in contact with a given target a number of times.

Repetitive transfer patterns occur as a result of any number of actions. Bloody hands, feet, and shoes are frequently the major causes of such patterns. The item comes in contact with a blood source, as in the instance of a shod foot stepping into a puddle of blood (see Figure 7.22). As the individual walks, blood is deposited each time the shoe contacts the target until it is depleted.

Defining this motion is based upon evaluating the dimming or diminishing of the pattern as the number of contacts increases. An analogy can be drawn to a parent following the muddy handprints of a child through a home. If all things are equal, the first contact leaves a greater volume than the next. Each subsequent contact depletes the available blood on the object, leaving less to make the next pattern transfer.

In considering the correlation of the patterns to the object that created them, remember that the patterns made later in the series often hold greater detail. These stains are much more likely to have individual characteristics of use to the forensic examiner.

Flows

Blood flows also provide critical information about motion. Obviously, blood flows will obey physical laws, specifically gravity. Of concern to the analyst are flows that indicate

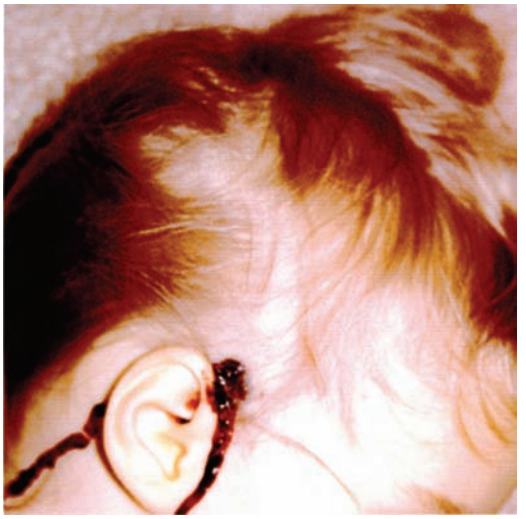


Figure 7.23 Two distinct blood flows from a bullet wound. The different paths taken by the two flows indicate a repositioning of the victim at some point.

body movement after the flow begins. Flows on the body that are irregular or defy expectations with regard to gravity may point to earlier positions of the victim (see Figure 7.23).

Another irregular flow that the analyst may encounter is due in part to capillary action. When an intervening object (quite often the body) is exposed to a large flow, or in some way dams a flow, the blood will tend to follow the contour of this object. If the object is later moved, the resulting flow pattern will likely appear abnormal or out of place.

Summary

Blood and bloodstains provide excellent indications to the analyst about motion. Understanding the minor nuances of directionality requires little effort because we observe liquid droplet behavior daily. Whether raindrops, bird droppings, or grease splashes, this concept is easily observed and recognized.

We also come to bloodstain pattern analysis with experience in swipe and wipe patterns. Whether we encounter paint, ink, or dirty mop water on a floor, the underlying motion or action is generally obvious to anyone. General sequencing of events by considering the volume of blood at different points in the scene may require a little more experience; nevertheless, its basis is still simple.

We hope it is obvious to the reader that motion is truly the most basic indication that bloodstains provide at the crime scene.

References

1. James, S.H. et al., *Principles of Bloodstain Pattern Analysis, Theory and Practice*, CRC Press, Boca Raton, FL, 2005, p. 82.
2. Hoymeyer, J.M., Blood Evidence, IAI Workshop Notes, unpublished.
3. Gardner, R.M., Directionality in Swipe Patterns, *Journal of Forensic Identification*, 2002, Volume 52, Number 5, p. 579.

Determining the Point of Convergence and the Area of Origin

8

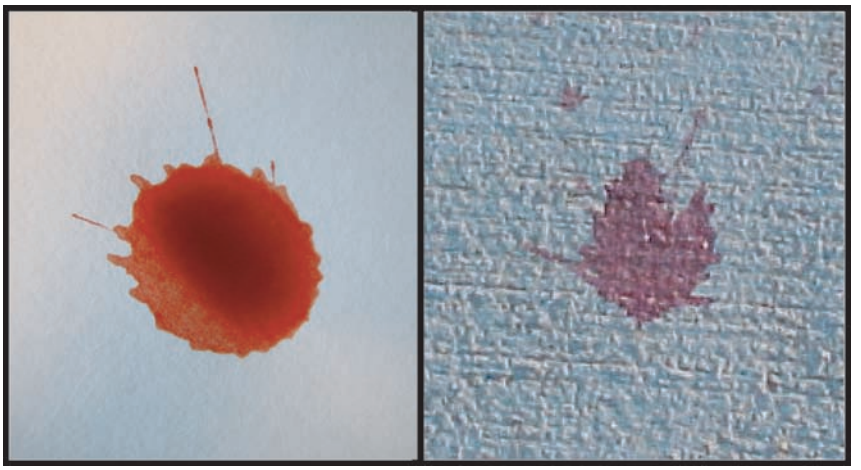
Our prior discussion of directionality and the evaluation of the path a given droplet was traveling logically lead us to the next step: defining from where the droplet came and determining what common convergence point several spatters may or may not have.

We can determine the area of origin for impact spatter patterns by following five steps. These steps are:

1. Identify well-formed spatter stains in the pattern.
2. Identify directionality of the stains.
3. Identify point of convergence for the pattern.
4. Identify impact angle of the stains.
5. Combine the information for area of origin.

Identify Well-Formed Stains in the Pattern

The concept of a well-formed stain is simply a stain that is symmetrical along its long and short axis. Figure 8.1 contrasts the difference between symmetrical and asymmetrical stains.



Symmetrical Shaped Stain Asymmetrical Shaped Stain

Figure 8.1 The symmetry of the stain is important to the analyst for both defining directionality and impact angle. In pursuing an analysis of the area of origin, the analyst chooses stains that are symmetrical. The stain on the left is symmetrical with clearly defined margins. The stain on the right, having impacted onto a rough surface, is not symmetrical. Defining a clear length and width, or identifying a long axis in such a stain is difficult.

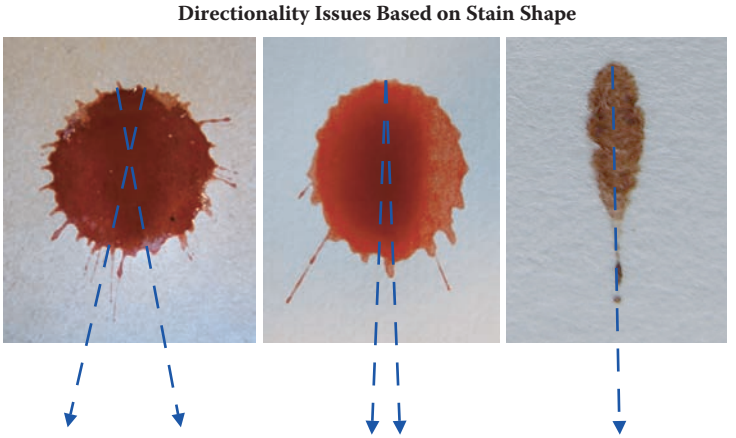


Figure 8.2 Directionality of a stain becomes more defined as the stain becomes more elliptical. In the round stain on the left, it is difficult to know where the long axis of the stain is. The middle stain provides a clearer idea of this long axis, but even in this instance, different analysts might view it in slightly different ways. The elliptical stain on the right allows for a very clear understanding of where the long axis is. Different analysts viewing directionality in this stain would not vary in any significant fashion.

Identify Directionality of the Stains

Chapter 7 concentrated on the idea of defining directionality in various types of stains. In spatter stains, directionality is defined by the long axis of the ellipse and the presence of scallops, satellites, and tails. The ability to recognize directionality is critical to locating a convergence point and the area of origin. Also discussed in Chapter 7 is the issue that the shape of the spatter stain limits what we learn about directionality. Elliptical stains offer information that is more specific regarding directionality; circular stains offer less (see Figure 8.2). As we discuss impact angle determinations, we will find there is a similar correlation of error associated with impact angles. Both issues (directional ambiguity and error rate associated with impact angle) functionally establish which stains the analyst will use in defining area of origin. As a general rule, stains that are generally circular (65° to 90° impacts) should not be utilized for this evaluation. Stains that have a clear elliptical shape (10° to 65°) can be used for directional evaluation.

Directionality defines the path of the droplet as it struck a target. Often this is described in general terms (e.g., left to right). This direction of travel can also be defined numerically by a specific angle. The directional angle, also known as the gamma angle, describes directionality as a specific angle (between 0° and 359°) as it relates to a reference point. Generally, this reference is north for patterns on horizontal surfaces and up for vertical surfaces. The directionality is established, and then the long axis of the stain is measured against the reference point. See Figure 8.3.

Identify Point of Convergence for the Pattern

Depending upon the specific questions raised about a given spatter pattern, the needs of the analysis may be different. In some instances, a point of convergence analysis (a top

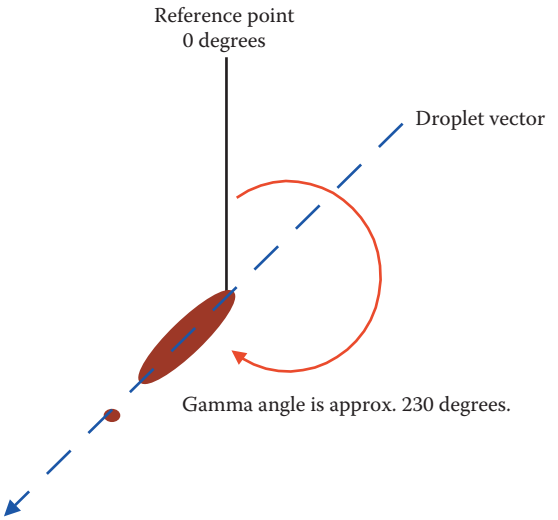


Figure 8.3 Directional or gamma angle is the angle between the long axis of a stain and a standard reference point. This angle describes the directionality, but does so from a standard reference point, thus allowing it to be used by forensic software.

view) may be sufficient to answer the questions. At other times, the analyst may require more detailed information, demanding the use of the area of origin evaluation methods.

For a stain on a horizontal surface if we can define the stain's directionality and then draw a reverse azimuth (that is, a line that extends backward along the path the droplet was following), we can be reasonably sure the droplet originated somewhere along this avenue. Looking down on the droplet's path in this top view there are no forces that affect the flight path.

In this top view, once set in motion, assuming no ricochet event exists, a droplet will follow a straight path from its source to its destination. Gravity and air resistance affect the droplet only in the vertical plane of its parabola (a side view perspective).[1]

For example, given Figure 8.4, stain #1 must originate somewhere along a reverse path as indicated by the directionality of the droplet. The only limits to the origin are the room's limitations or any intermediate obstacles. If Figure 8.4 represented the room boundaries and the possible reverse path for stain #1 extends 13 ft, then the drop's origin must lie somewhere within those 13 ft. With only one stain, the resulting parameter of possible origins is very wide.

If we introduce a second stain, as in Figure 8.4, we can then look for a point where the two paths intersect. The process is no different from the technique known as resection in map reading. By taking two known points and applying reverse azimuths from each, we define an unknown point where the azimuths cross. In this instance, the unknown point is the likely source for both stains, their point of convergence.

Keep in mind that this convergence "point" is likely to be an area. The individual lines created by these reverse azimuths will cross but not at a distinct point (e.g., a specific XYZ position in space) (see Figure 8.5). However, the wider the radiating pattern of spatter involved, the more likely we can resolve the convergence to a more refined point (see Figure 8.6).

By limiting ourselves to this top view dimension, we certainly gain simplicity in the evaluation. We also gain an inherent difficulty. If our circumstances limit us to only a

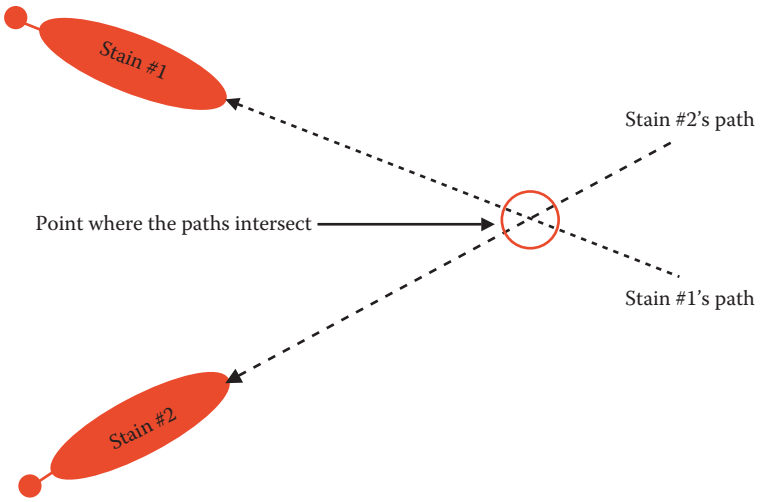


Figure 8.4 By following the reverse vector of each droplet to the point where they intersect, we can establish a probable point of convergence in two dimensions.

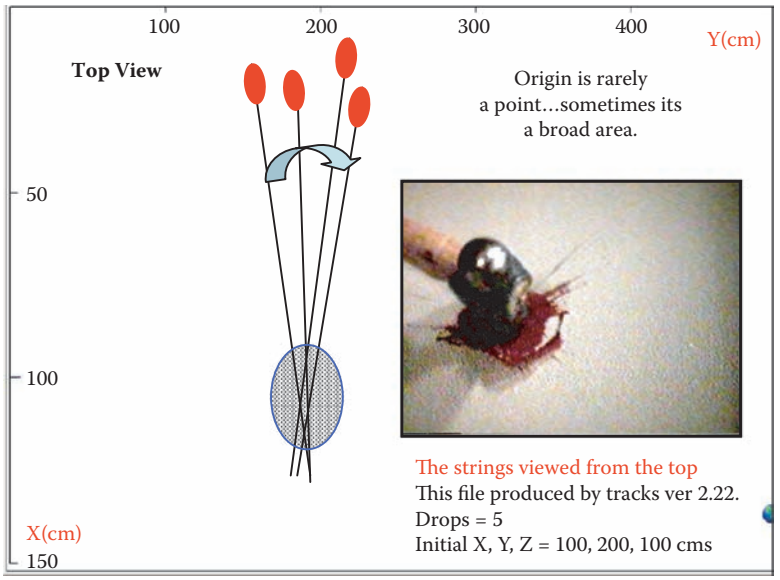


Figure 8.5 At the convergence, the lines will rarely cross each other at a single point. The convergence point is often an area as well.

few stains, it is always possible they are the result of more than one event. That is, an event created stain # 1, followed by another unrelated action that caused stain # 2. Given this situation, the points where their reverse paths cross is simply coincidental and has no investigative significance.

Widespread within a scene and showing no common convergence point, we would easily recognize such stains as separate actions. Found in proximity to each other, the likelihood of a coincidental convergence of the flight paths increases. Unfortunately, we may choose to read this convergence as a single origin for both stains. With only a few stains to work with, it may be difficult to recognize such an error.

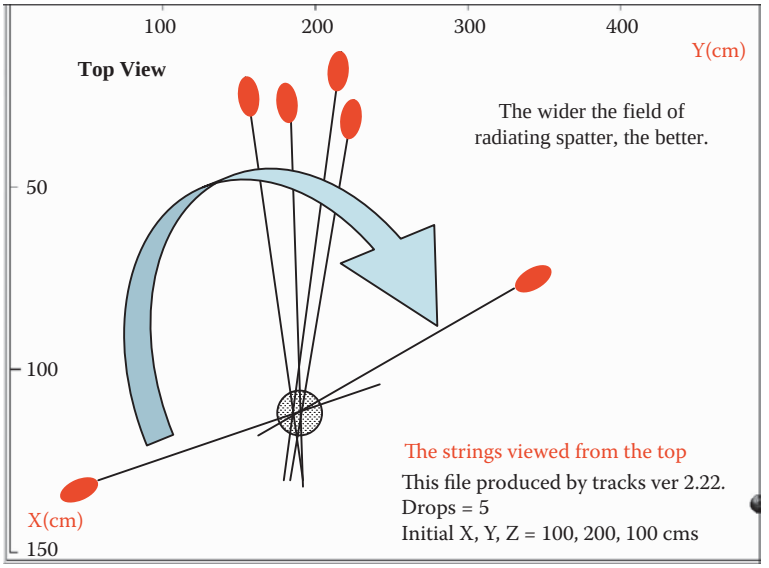


Figure 8.6 The wider the field of radiating spatter, the more refined the convergence point becomes. Note that the inclusion of the far right and far left stains functionally tightens the convergence point as compared to that observed in Figure 8.5.

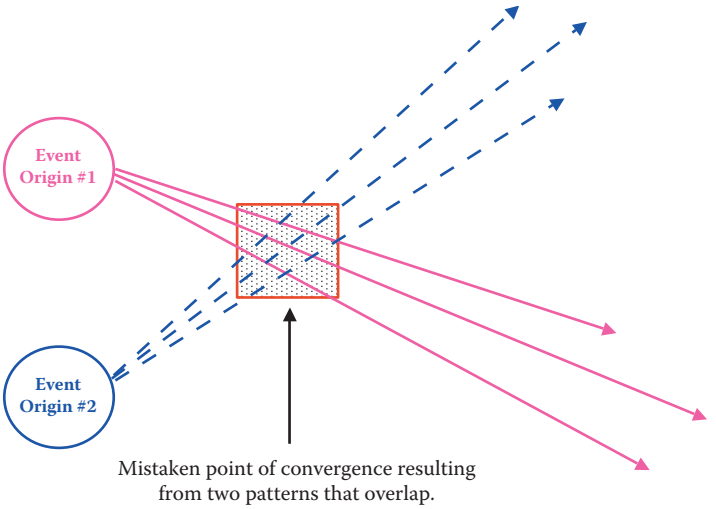


Figure 8.7 In addition to the possibility of two stains having a coincidental intersecting point, it is also possible for two patterns to overlap in this fashion. If this condition is not considered, it might well result in a mistaken point of convergence for both patterns.

The same is certainly true when viewing two adjacent patterns. We may see a coincidental convergence for two patterns and read this as the source for both. Figure 8.7 illustrates the possible error when viewing patterns from two closely located impacts.

As the number of evaluated stains increases, our level of confidence increases as well. The more paths we find that intersect a given area, the more likely it is that we have a true point of convergence. Even in circumstances of multiple overlying events with the spatter intermixed, the primary convergence points may still be evident. In this situation, the

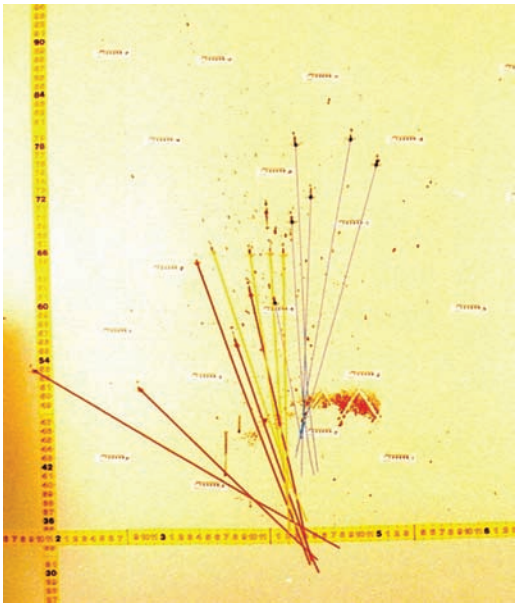


Figure 8.8 An example of using graphic tape to demonstrate the point of convergence in a spatter pattern.

various paths may cross at several locations, but where we find clusters of intersecting paths will establish the primary convergence points of the various events.

What this top view method of analysis of the convergence point does not establish is the three-dimensional origin of the spatter, the point above the convergence point where the spatter originated. This location is known as the area of origin, a position in three-dimensional space. In the top view approach, we establish a convergence in two dimensions and accept the flight paths originate somewhere above it. Once again, the possibility of multiple events always exists. The analyst may be viewing spatter from two or more events that originated at the same location in a room, but from different heights during different events (e.g., one impact at 6 ft, another at 3 ft).

As described, the top view convergence technique is effective in and of itself in some instances. Used in conjunction with Toby Wolson's[2] technique of Roadmapping, which is discussed later in the book, it represents a functional method of portraying this convergence in the scene (see Figure 8.8). This information alone limits the possible area where the event could have originated.

On vertical surfaces, point of convergence is more problematic. In some limited instances, we can use this method, but because gravity and air resistance affect the path of the droplet in the vertical plane, directionality is also affected. This concern will be discussed in detail later in the chapter and we will explain the issue more fully.

To this point, we have narrowed our scope to finding the point of convergence along the paths of the stains of interest. The converging lines of these reverse vectors establish a point of convergence for the pattern. To more effectively limit the source of the pattern, we must look at the fight paths in the vertical plane, a side-view approach of the target. This requires including the stain's impact angle in the analysis.

Identify Impact Angles for the Stains

Dr. Victor Balthazard can be credited with having recognized that a relationship exists between the length and width of the resulting stain and the angle at which the droplet impacts. The shape of the stain defines the angle of impact. In general terms what this means is the more circular the stain, the more perpendicular the angle at which it struck the target surface (e.g., 90°), whereas the more elliptical the shape, the more acute the angle of impact (e.g., 10°). See Figure 8.9. With practice and experience and by observation alone, the analyst will recognize the general angle of impact based solely on the shape. This angle can also

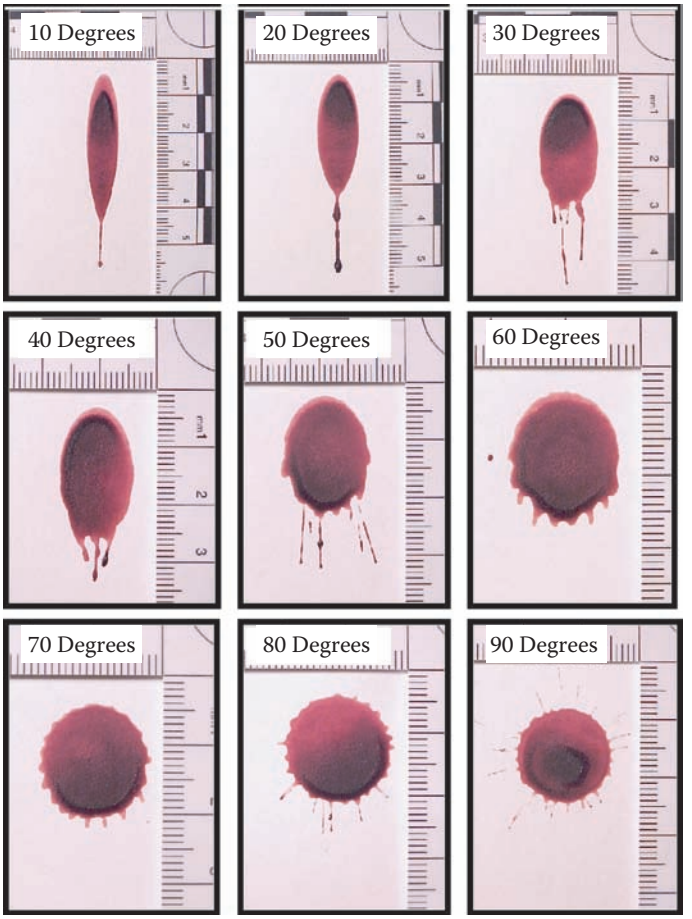


Figure 8.9 Impact angle and stain shape. There is a direct correlation between the shape of a stain and the angle at which it struck a target surface. The more elliptical the stain's shape, the more acute the angle of impact. The more circular the stain, the closer it fell to 90° on the target.

be computed to within a few degrees of the actual impact angle based on this relationship. MacDonell later refined Balthazard's concept applying the width/length ratio in conjunction with specific trigonometric functions (e.g., sine function). This allows the analyst to use straight-line geometry techniques in defining the bloodstain event.[3]

Given a well-formed stain where we can accurately measure the width and length, we can easily establish the impact angle using Dr. Balthazard's concept.[4] See Figure 8.10.

To apply the impact angle formula it is important to understand that in right triangles certain relationships exist between the

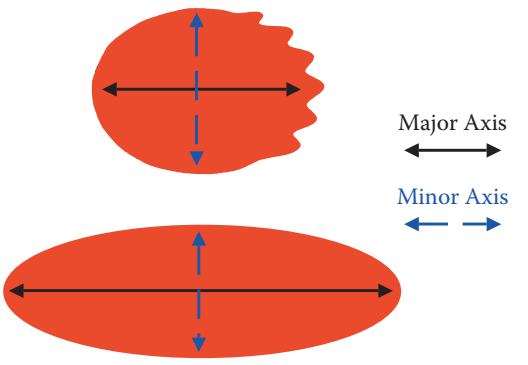


Figure 8.10 Our concept of a "well-formed" stain means simply that if we divide the stain along its major and minor axis, the opposite halves would be generally equal to each other.

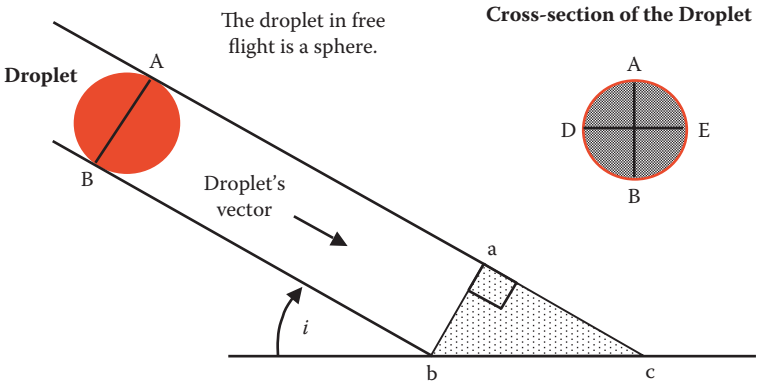


Figure 8.11 The relationship of the droplet to an imagined right triangle. Using the sine function and this relationship, the analyst can establish the angle of *i*. This is the droplet's impact angle.

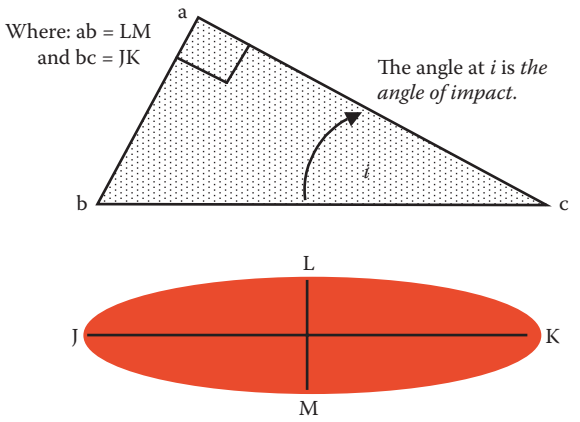


Figure 8.12 We can draw an analogy between the right triangle formed in Figure 8.11 and our bloodstain. Line ab is analogous to line LM, as is bc to JK. Thus, the length and width of the stain are quantities we can apply using the sine function to determine the impact angle (*i*).

angles of the triangle and the length of its sides. These relationships are trigonometric functions such as sine, cosine, and tangent. These relationships are in no way dependent upon the factors found at the crime scene; they are mathematical in nature. What we do is make an analogy to our scene using these relationships.*

Imagine a right triangle formed between the droplet and the target surface as the droplet strikes. Figure 8.11 outlines how this triangle might look. A blood droplet in flight is in the shape of a sphere. Therefore, in viewing Figure 8.11, Line DE (the width) can be considered equal to Line AB (the height) of the sphere. An analogy can then be drawn between Line ab and bc and the width and length of the resulting stain (see Figure 8.12). Based on the analogy, Line ab is represented by Line LM of the stain and Line bc is represented by Line JK of the stain.

* Although one might infer from Figure 8.11 that a 1:1 relationship exists between the size of the droplet and the size of the resulting stain (e.g., AB = ab), this is not the case. As the droplet collapses there is a lateral spread of the liquid. We do not yet fully understand this lateral spread and resulting ratio; however, it has no apparent effect on the actual application of the process.

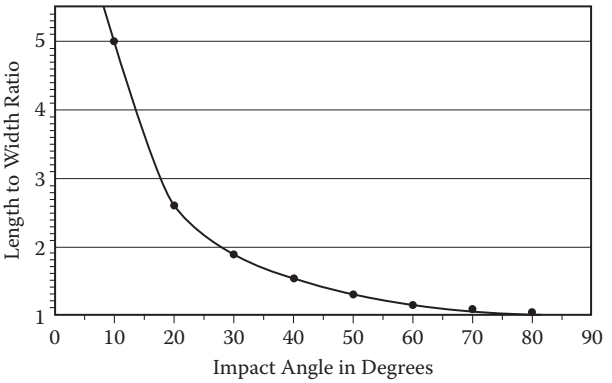


Figure 8.13 A length-to-width ratio chart. By dividing the length of the stain by the width, we generate a number that is always greater than 1. The analyst finds this number on the vertical axis, and then reading to the right locates the corresponding point where the graph line intersects. The angle listed below this point is the approximate impact angle. For example, the L/W ratio of 1.9 equates to a 30° impact angle.

As a result of this analogy, we have two known quantities from our crime scene which we can apply to a formula. By measuring the stain's length (Line JK) and width (Line LM) and applying them to the following formula, the droplet's impact angle becomes evident:

$$\text{Sine } i = \text{Width (ab)/Length (bc)} \quad (1)$$

$$\text{Inverse Sine (ASN) } i = \text{Impact Angle} \quad (2)$$

Example:

Width = 3 mm
Length = 5 mm
0.6 (Sine i) = 3/5 (Width/Length)
Inverse Sine i (0.6) = 36.8
Impact angle = approximately 36 to 37°

It is important to recognize that the formula provides the analyst with an estimate of the impact angle. The precision of the math should not be construed to mean a similar precision in the definition of the angle. Issues related to the ballistic path of the droplet preclude us from accepting this angle as absolute. As a rule, impact angles are considered to be accurate to within 5° to 7°. It has always been recognized that circular shaped stains presented a greater error level. Recent studies demonstrate that when dealing with stains that impact between 10° and 45°, the error rate is only 2° to 3°. This error rises to 6° to 7° for stains impacting at 60°. After 60°, the error rate rises dramatically. As with the concern of directionality, error rate issues demand that the analyst carefully consider what stains are utilized for area of origin determinations.

In addition to using a calculator with a sine function, there are two other related methods for determining impact angle. The first involves the length/width ratio chart (see Figure 8.13). This chart is based on Balthazard's original research. This basic experiment is repeated in every basic bloodstain pattern analysis class. The analyst divides the measured length of the stain by the width, resulting in a number greater than 1. If the result is less

Degrees	Sine	Degrees	Sine	Degrees	Sine	Degrees	Sine
1	0.0175	26	0.4384	51	0.7771	76	0.9703
2	0.0349	27	0.454	52	0.788	77	0.9744
3	0.0523	28	0.4695	53	0.7986	78	0.9781
4	0.0698	29	0.4848	54	0.809	79	0.9816
5	0.0872	30	0.5	55	0.8192	80	0.9848
6	0.1045	31	0.515	56	0.829	81	0.9877
7	0.1219	32	0.5299	57	0.8387	82	0.9903
8	0.1392	33	0.5446	58	0.848	83	0.9925
9	0.1564	34	0.5592	59	0.8572	84	0.9945
10	0.1736	35	0.5736	60	0.866	85	0.9962
11	0.1908	36	0.5878	61	0.8746	86	0.9976
12	0.2079	37	0.6018	62	0.8829	87	0.9986
13	0.225	38	0.6157	63	0.891	88	0.9994
14	0.2419	39	0.6293	64	0.8988	89	0.9998
15	0.2588	40	0.6428	65	0.9063		
16	0.2756	41	0.6561	66	0.9135		
17	0.2924	42	0.6691	67	0.9205		
18	0.309	43	0.682	68	0.9272		
19	0.3256	44	0.6947	69	0.9336		
20	0.342	45	0.7071	70	0.9397		
21	0.3584	46	0.7193	71	0.9455		
22	0.3746	47	0.7314	72	0.9511		
23	0.3907	48	0.7431	73	0.9563		
24	0.4067	49	0.7547	74	0.9613		
25	0.4226	50	0.766	75	0.9659		

Figure 8.14 An abbreviated sine function table. In this method, we divide the width by the length of the stain, which always generates a number less than 1. The analyst then looks for the closest corresponding number under the sine column of the chart. The number adjacent to this lists the degree of the impact angle. For example, a 0.5 W/L ratio equates to a 30° impact angle.

than one, you have reversed the length and width in the formula. Using the result, the analyst locates the corresponding number on the vertical axis of the L/W ratio chart. Where the line intersects this point, one simply reads the angle listed on the lower axis.

The second method involves dividing the width of the stain by the length and comparing this number to a sine function table (see Figure 8.14). In this instance, the result will always be less than 1. The analyst finds the corresponding number on the sine function table to determine the angle. A sine table simply eliminates the need for a scientific calculator.

Stain Measurement

Measuring the stain is obviously critical, as this provides the analyst with a length and width. In considering the measurement, the analyst measures only the main body of the

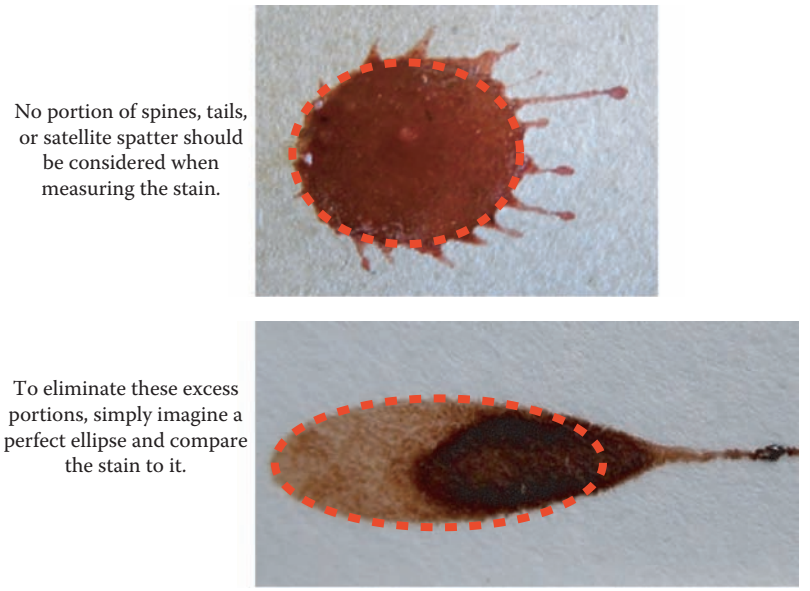


Figure 8.15 By comparing the stain to an imagined ellipse, one can generally distinguish those portions of the stain to disregard during the measurement process. Including scallops, spines, and satellite spatter in the measurement will result in a skewed estimate of the impact angle.

stain. This measurement must exclude any portion of the satellite, scallop, or spine present in the stain. To accomplish this, one need simply envision a perfect ellipse superimposed on the stain. By choosing a point on the stain that naturally completes the ellipse, the remaining tail portions are not subjectively drawn into the calculation (see Figure 8.15).

It is important to understand that the inclusion of any excess scallop or portion of the spine will change the overall length-to-width ratio. For example, consider a stain with an actual length of 5 mm, width of 4 mm, and a scalloped tail of 0.5 mm. Given such a stain, the following is possible:

Correct Measurement and Evaluation
Length: 5 mm
Width: 4 mm
Impact Angle: 53°

Incorrect Measurement and Skewed Evaluation
Length: 5 mm plus 0.5 mm scallop
Width: 4 mm
Impact Angle: 46°

In this example, the small excess scallop adds an error of 7° to what we already accept as an *estimation* of the impact angle. Obviously, by including these excess portions, the analyst can change the calculated impact angle significantly. Unfortunately, there are no absolute rules for closing out the ellipse. The analyst must judge each stain individually and attempt to eliminate these scalloped edges and tail portions from the measurement. Figure 8.16 and Figure 8.17 show examples of what portions of the stain the analyst should

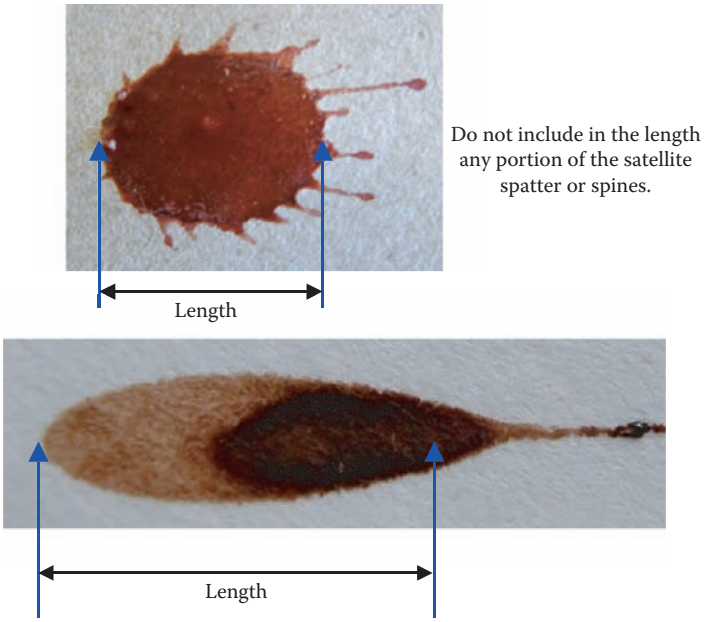


Figure 8.16 The length of the stain is measured along its major axis. The analyst must exclude from the measurement any spines, scallops, tail, or satellite stains that may be present.

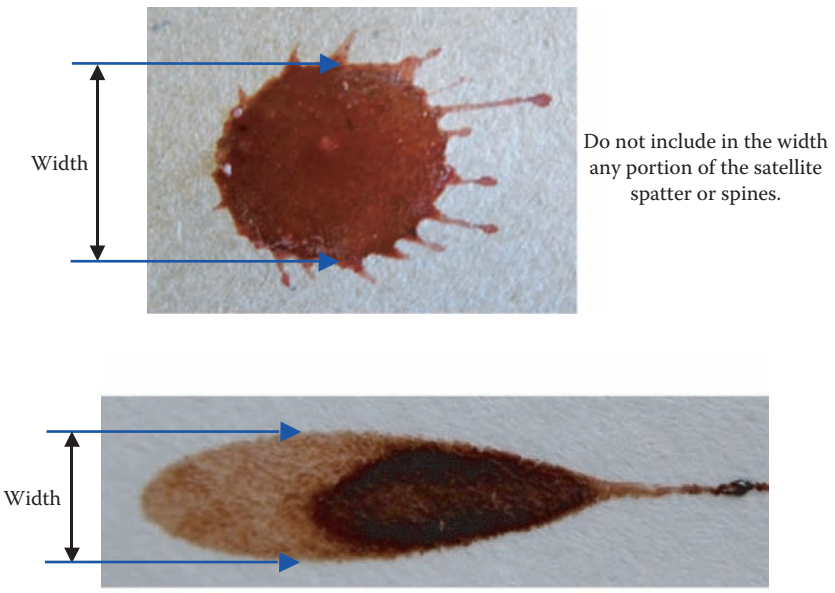


Figure 8.17 The width is measured along the minor axis of the stain. Although satellite spatter are less a concern when measuring this axis, scallops along the outer edges of the stain are often encountered. Do not include the scallop in the measurement.

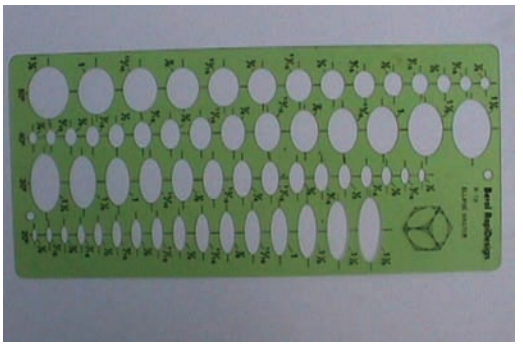


Figure 8.18 An ellipse template. Although not convenient for on-scene work, the comparison of the stain to an ellipse template in training and for practice assists the analyst in recognizing what portions of the stain to measure.

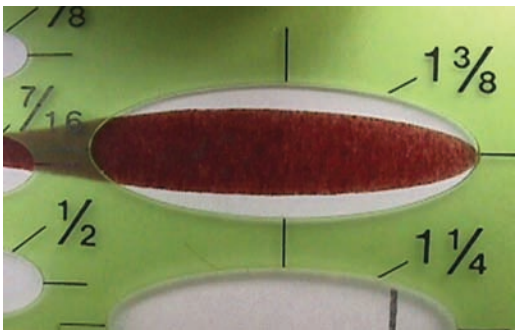


Figure 8.19 In this example, an ellipse of 20° overlays a stain with a 10° impact angle. The comparison makes it evident the two do not match.

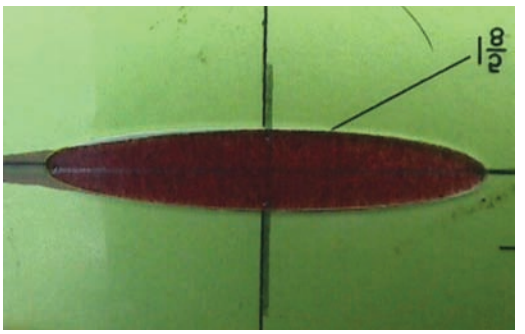


Figure 8.20 In this example, an ellipse of 10° overlays the same stain as shown in Figure 8.19. The fit is almost perfect. Note the left end of the ellipse, the stain's tail extends well past the perfect ellipse. The area of the stain extending beyond the ellipse should be ignored in the measurement of the stain.

include and exclude. Although the tail structures will only cloud the length measurement, scallops may appear on both the sides and end of the stain, making it more difficult to identify the true edges of the stain both in the length and width aspects.

Closing out the ellipse and locating the end of the stain is an important consideration. It is only through practice that one learns to do this well. The use of an ellipse template (see Figure 8.18) can help in identifying the end of a bloodstain ellipse. This endpoint of the stain (the point farthest from the source and usually scalloped or attached to a tail) is often hidden by the tail and satellite structures. This makes it difficult for a new analyst to differentiate bloodstain lengths, particularly those in the 10° to 35° range. By simply comparing the bloodstain to a manufactured ellipse template, it is easier to recognize where the natural closing of the ellipse is. For example, Figure 8.19 shows a 20° ellipse overlaying a 10° stain. The outline of the template obviously does not align with the outside edges of the bloodstain. Figure 8.20 shows a 10° template overlaying a 10° bloodstain and the two are nearly a perfect fit.

As bloodstains vary in volume, they will also vary in size, even if they impact at the same angle. In order for the ellipse template to be a functional means with which to

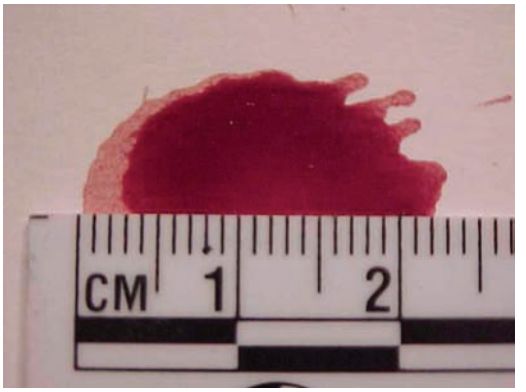


Figure 8.21 Measuring a stain with a simple ruler. The ruler is scaled only to 1 mm; thus, the only reasonable estimate possible using this scale of reference is to the nearest 0.5 mm.

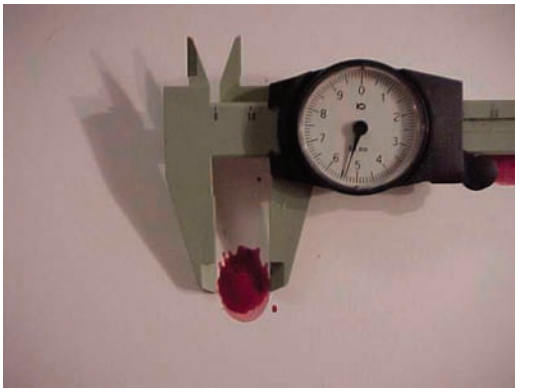


Figure 8.22 Measuring a stain with the micrometer. The analyst matches the inside edge of the caliper to the stain edges and then reads the stain measurement using both the scaled bar (10 mm) and the needle gauge (5.4 mm). The short axis of this stain measures 15.4 mm.

measure bloodstains at the crime scene, the analyst must have a set of ellipses for not only the varying degrees required, but also to match the full size range of bloodstains encountered. As a result, the template as a measuring mechanism is not feasible due to cost and the problem of carrying the templates around. However, the template method is excellent in training. New analysts will find it gives them a greater level of confidence in identifying the natural closing point of the stain.

The specific methods the analyst uses to measure the stain are unimportant, so long as the analyst is comfortable with both *what* he is measuring and his measuring device. Options include:

- Measuring the stain with a ruler or micrometer
- Measuring the stain with a drafting divider
- Measuring the stain with a photographic loupe

The use of a simple ruler is certainly functional; however, the analyst is limited by the smallest scale present on the ruler. For instance, if the ruler is scaled to 1 mm, the analyst can only measure to the closest .5 mm. Any estimate beyond the .5 mm would be subjective (see Figure 8.21). The micrometer offers an additional advantage, as most are scaled to the level of .1 mm. When one considers that the typical stain being measured is not the large 4 to 10 mm variety, but rather the smaller 1 to 4 mm stains found in impact events, the use of the micrometer is much more functional (see Figure 8.22).

The use of a photographic loupe is also effective. The scale limitation previously discussed applies to any measuring device and this can be a problem with many photographic loupes as well. Loupes come in a variety of styles and configurations and not all have a reticule, scale, or functional measuring mechanism. Before acquiring one, the analyst should verify that there is a scale and that it is functional for his intended purpose (see Figure 8.23 and Figure 8.24).

The third method for measuring a bloodstain is with a drafting divider (see Figure 8.25). The analyst adjusts the dividers to match what appears to be the widest part of the short

Figure 8.23 A photographer's loupe in use to measure a stain.

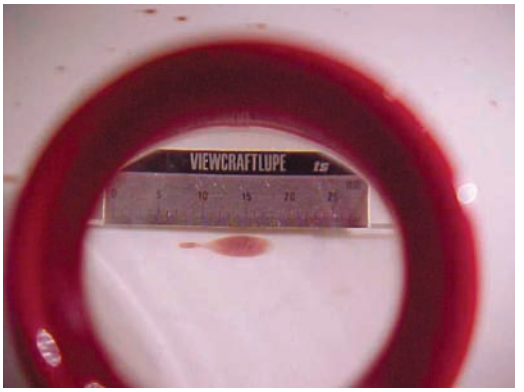


Figure 8.24 The view through the loupe. The loupe should include a functional scale situated in the viewfinder in a manner that will allow easy comparison of the stain to the scale.

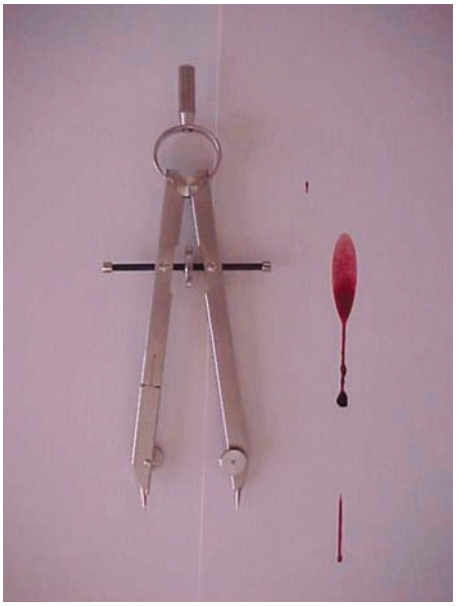


Figure 8.25 Use of a drafting divider to measure a stain is another method, which allows the analyst to effectively decide what portions of the stain to include or exclude in the measurement.

axis (see Figure 8.26). Maintaining this adjustment, the analyst runs the divider arms down from the top (the leading edge of the stain), along the length of the stain. The analyst then marks the point where the divider points both touch the bloodstain (see Figure 8.27). With the same adjustment the procedure is followed from the opposite end of the stain. Once again, the point where the arms touch is marked (see Figure 8.28). This process will identify the true widest area of the short axis of the stain. It is actually a point, but our eyes tend to see it as an area. The comparison and marking from both the top and the bottom of the stain ensures finding the widest point of the short axis.

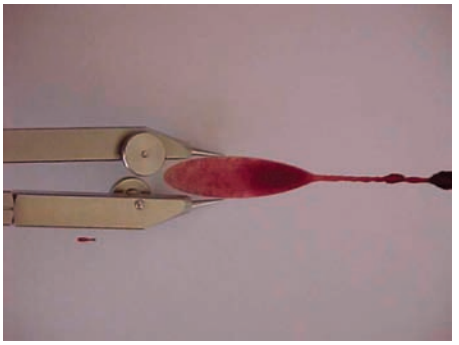


Figure 8.26 In the first step, match the divider points to the widest part of the outside edges.

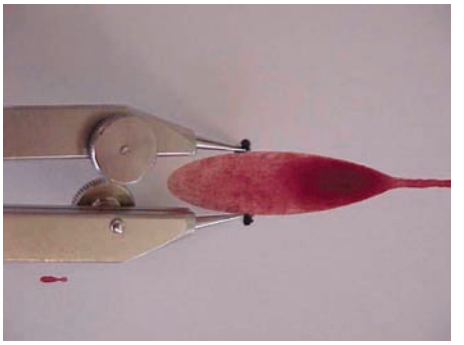


Figure 8.27 Without adjusting the arms, place them at the top (the leading edge of the stain) and move them down the body until the arms appear to touch the edge of the stain. Mark both points.

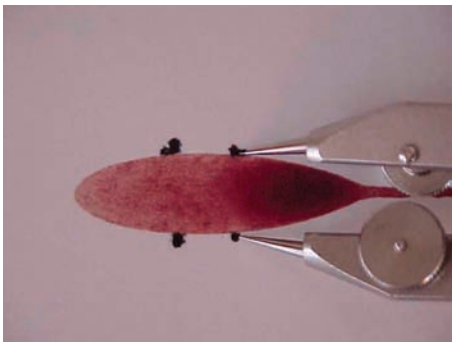


Figure 8.28 Without adjusting the arms, move them in the same fashion from the bottom of the stain (the edge with the tail and scallops) back toward the middle of the stain until the arms appear to touch the edge of the stain again. Mark these points.

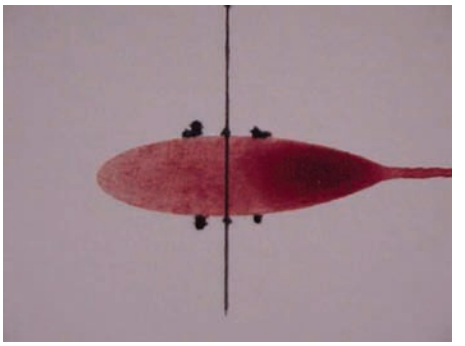


Figure 8.29 By splitting the difference of the measurement between the two marks, we identify the widest part of the stain. This point often appears as an area when if fact it is really a point.

In order to locate the long axis length, the analyst splits the difference between the two previously established marks (see Figure 8.29). This third mark is the center of the long axis. The divider points are placed at the central mark and at the top of the stain (see Figure 8.30). This identifies a true half of the ellipse. By multiplying this measurement by two, the analyst finds the actual measurement of the long axis. In order to visualize this point on the stain itself, simply rotate the top divider arm down to the bottom of the stain while leaving one arm in the center of the stain (see Figure 8.31). Then, keeping the bottom divider point in place at this new point, readjust the top divider arm from the center to the top of the stain (see Figure 8.32).

Combine the Information to Establish an Area of Origin

Having learned to determine the impact angle, we combine the convergence point (the top view) and the impact angle (the side view) information in order to identify the area of origin for the spatter event. This is a location in 3-dimensional space. For many years,

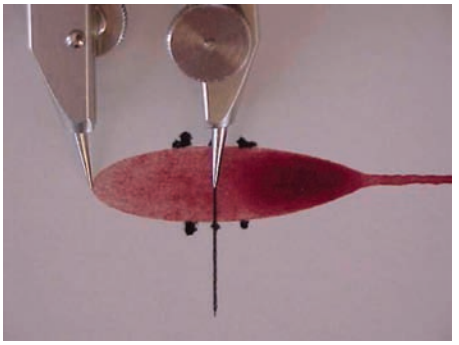


Figure 8.30 To locate the long axis length, place one arm on the center line and the other on the top (leading edge) of the stain. This measurement doubled identifies the length of the long axis.

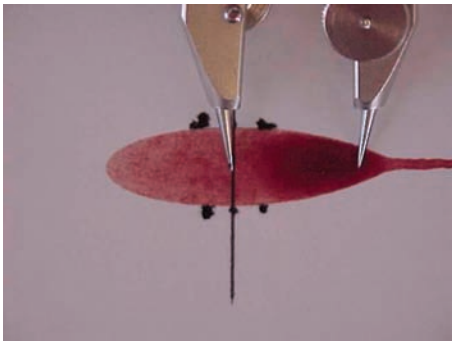


Figure 8.31 To visualize this point, without adjusting the arms and keeping the arm on the center point, simply rotate the other arm to the other end of the stain (the trailing edge).

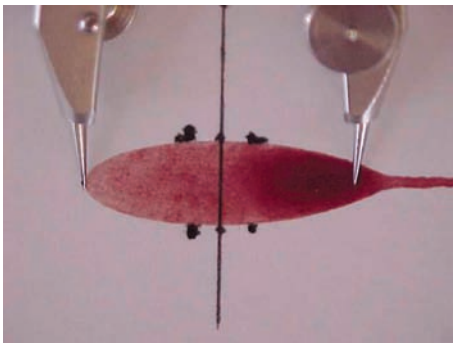


Figure 8.32 As with the ellipse template comparison method, note that there is an area on the trailing edge (where the tail and stain meet) which is not included when measuring the stain length.

this location was referred to as the point of origin; but "point" suggests an actual point, a specific position in the X, Y, and Z planes. Because of the issues associated with defining directionality and impact angle we recognize that what we are defining is a general area, not a point. In some instances, this area may be quite specific, but in others, it may be quite large. For this reason, the "point of origin" is now generally described as an area of origin. Both terms refer to the same thing and are synonymous.

For the sake of simplicity in the following example we will leave all stains on a single surface. See Figure 8.33. The flight paths of the four stains appear to have a common convergence point in the scene. Our stains are "well-formed" and the analyst measures each and applies the sine formula, identifying each stain's impact angle.

Accept for the example that based on the width/length ratio the stains impacted as follows:

- Stain #1: 30°
- Stain #2: 60°
- Stain #3: 50°
- Stain #4: 40°

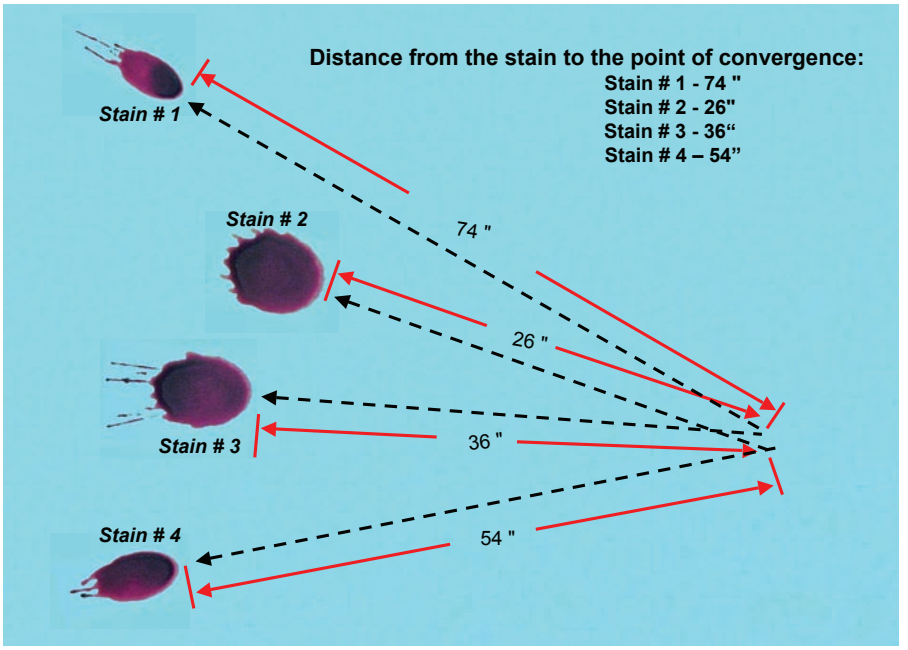


Figure 8.33 An example of using point of convergence evaluations. In this instance, we have four stains with a common convergence point and we wish to determine if they share a common area of origin. We measure the distance from the base of each stain to the convergence point. We then combine that information with the impact angle in a graph (Figure 8.34), which allows the analyst to visualize the area of origin for the spatter.

For purposes of the example, imagine that the analyst then measures the distance from the convergence point to the rear edge of each stain. In this instance, the analyst found:

- Stain #1 is 74 in. from the convergence.
- Stain #2 is 26 in. from the convergence.
- Stain #3 is 36 in. from the convergence.
- Stain #4 is 54 in. from the convergence.

Graphing Points of Origin

One method of combining this information is to use a graph. To do so, the analyst draws a graph with a positive X axis and a positive Z axis. The Z axis represents the point of convergence; it graphs the height above the target involved. The X axis represents the target plane; it graphs the distance of the stain from the point of convergence. The two axes are scaled the same, with whichever scale we choose.

The analyst begins by placing a mark for each stain along the X axis at the appropriate distance (e.g., 74 in.). From this point, using a protractor, a line is drawn along the indicated angle of impact extending it to the Z axis. The analyst repeats this process for each of the stains involved. The resulting graph would look like that in Figure 8.34. The point where the lines converge on the Z-axis scale establishes the probable area of origin for the spatter above the convergence point on the target.

As we draw the lines along the angle of impact for each stain, a common area of origin on the vertical Z axis should become evident, assuming of course a true common origin exists. If

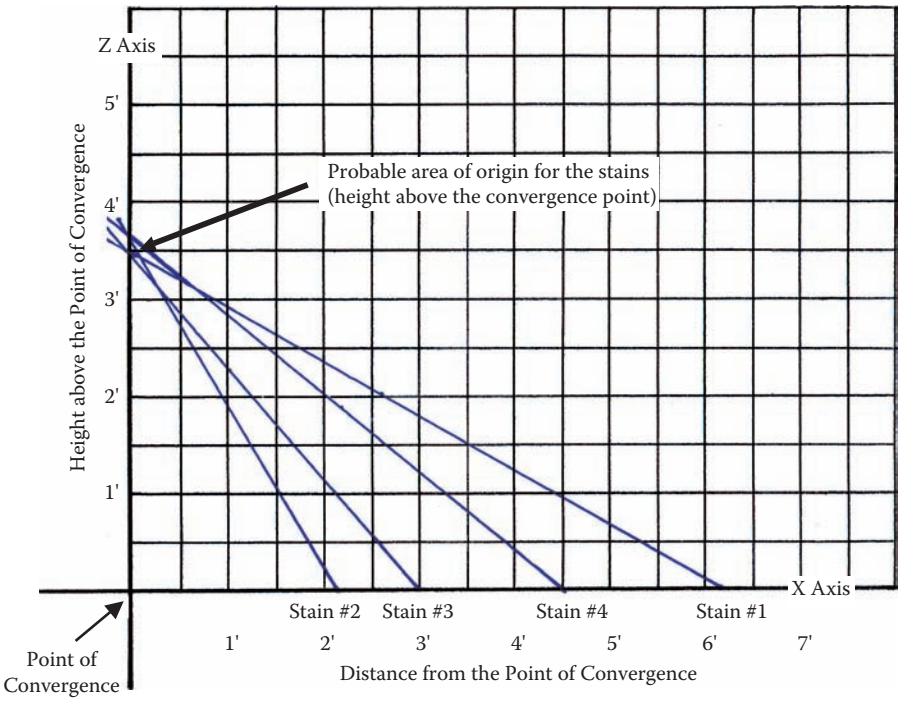


Figure 8.34 Graphing the area of origin. We mark the distance from the convergence point on the X axis and then draw a line to the Z axis at the indicated impact angle of each stain. Where the line crosses the Z axis is the probable point of origin (height above the target) for that particular stain. In this instance, the stains appear to have a common area of origin approximately 42 in. above the target.

the spatters evaluated are the result of two or more different events that occurred at different heights, that too would become evident. Figure 8.35 is an example of what one would expect to see in a situation involving two impacts at different heights over the same location. Remember, the Z axis represents the area above a single point of convergence on the target. When viewed from above, all the paths for the stains involved cross at this point. Viewed only from a top view perspective, one might choose to believe they originated from a single event.

By considering the impact angles in conjunction with the top view for Figure 8.35, a distinct grouping becomes evident with a common origin close to the target's surface. Another group is also evident with an origin higher than the first. This tends to indicate two different spatter-producing impacts at that convergence point.

Defining Area of Origin with the Tangent Function

By using a scientific calculator, it is possible to forego the graphing process and simply calculate this distance above the point of convergence for each stain. The analyst does this using another relationship related to right triangles, the tangent. Figure 8.36 shows the relationships of the scene to this imagined triangle.

The first step in making this determination is to identify stains that appear to have a common convergence. As in the graphing method, the analyst measures the distance from these stains back to the point where the stains have a common intersection. The analyst also determines the impact angle of each stain.

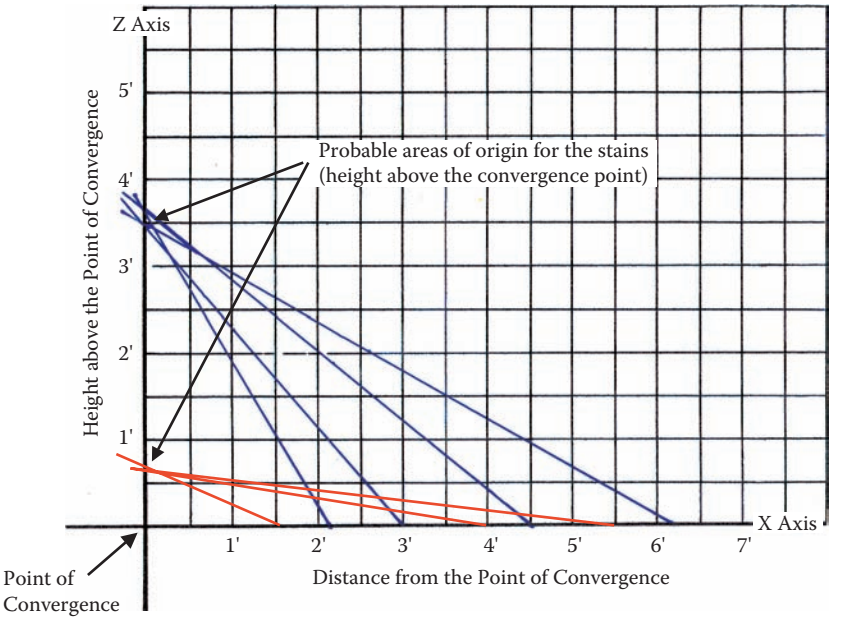


Figure 8.35 A graph indicating two areas of origin. In the scene from an overhead view, all the stains appear to share a common point of convergence. The inclusion of the impact angle information adds an additional dimension making it apparent that two separate groups are present, suggesting two separate events.

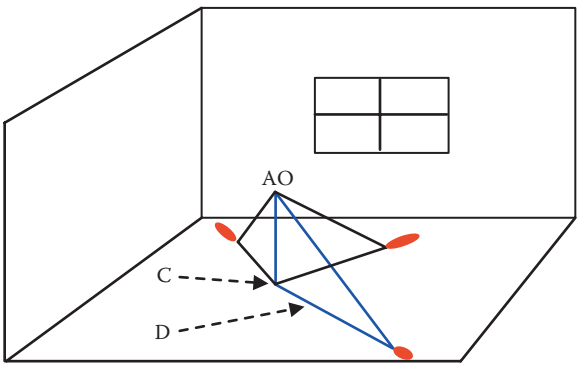


Figure 8.36 The base of each stain's position, the point in two-dimensional space where their paths converge (c), and their area of origin (o) define another right triangle.

To determine area of origin, the analyst uses the following formula:

$$\tan i = H/D \tag{3}$$

where i equals the known impact angle, D equals the distance to the convergence point, and H equals the unknown distance above the target surface (See Figure 8.37). For example:

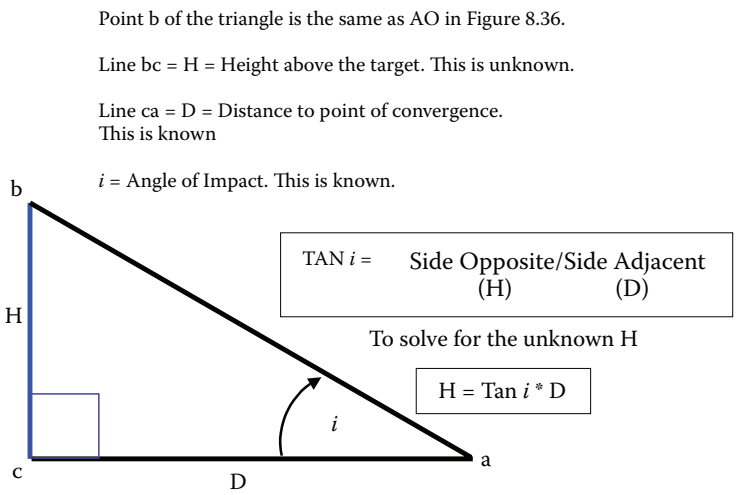


Figure 8.37 Our right triangle from Figure 8.36 further defined. We know the distance from the stain to the point of convergence (ca) and we can establish the impact angle (*i*). Using this information in the formula tan *i* = H/D, we simply balance the equation and solve for the unknown H. Thus, H= tan *i* × D.

$$i = 19°$$

$$D = 25 \text{ in.}$$

$$\tan 19 = .344$$

$$0.344 \cdot 25 = 8$$

To solve for H we simply balanced the equation by multiplying tan *i* by D, giving H = 8.66 in. This procedure is convenient and provides immediate feedback at the scene. Once again, the analyst requires a calculator with trigonometric functions to use this method.

Three-Dimensional Evaluations of Area of Origin

A final manner of evaluating area of origin is in a graphic three-dimensional fashion. This is possible either in a physical sense, using the "stringing" technique, or by using computer-aided analysis tools.

Stringing Scenes

Stringing is a basic method taught to bloodstain analysts. Because of computer technology, its place in on-scene analysis is slipping into the past, but stringing is still considered useful as a visual aid to help explain area of origin to both juries and students (see Figure 8.38). The true origin of stringing is somewhat in question. MacDonell is the first person to describe the process itself, yet we usually credit Balthazard et al. for developing the foundation of stringing.[5]

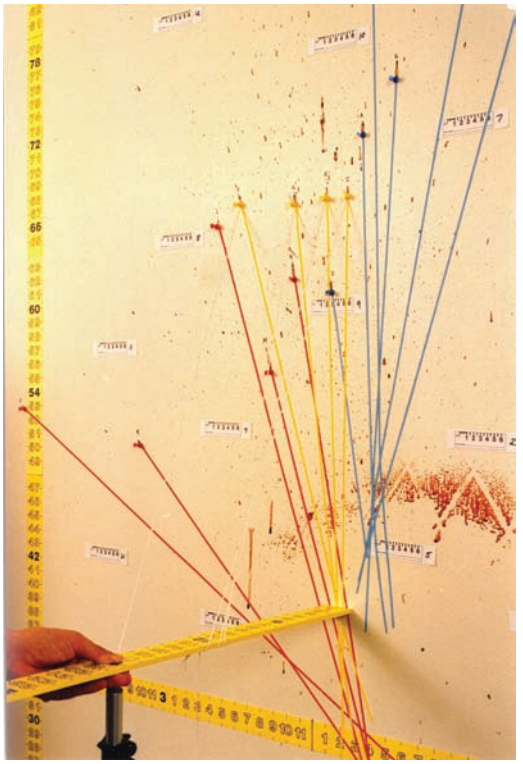


Figure 8.38 An example of on-scene stringing in combination with the use of graphic tape. The graphic tape demonstrates the point of convergence, while the strings demonstrate the area of origin. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL.)

Whomever the actual originator, the process is simply a physical extension of what we have described to this point. Stains from the pattern are chosen and impact angles determined. Based on directionality and convergence points, thread or string is taped in place at the base (the leading edge) of the actual stain. This base is the point on the long axis of the stain, opposite the scallops, tail, or satellite stains. The string is then extended back along the indicated path and angle. The most effective way to find this path is with a laser protractor. The protractor is set at the indicated impact angle and aligned with the directional angle (the long axis of the stain). The laser is then turned on and the point where the laser strikes a nearby surface is marked. A string is then attached from the stain to this point (see Figure 8.39). This process is repeated for each stain evaluated. Not only does the laser protractor reduce the subjectivity of aligning the string, it also reduces the level of labor necessary to string a scene. As more and more strings are introduced into the scene, a generalized convergence in space will begin to form (see Figure 8.40).

Stringing as a technique has several drawbacks that owe to its demise. First, it requires the expenditure of immense effort. Placing the strings into the scene and finding objects to attach them to is a chore. The analyst ends up interjecting tripods or extending strings across rooms to opposite walls. This of course produces clutter, which the analyst must move around while completing the stringing process. A second and perhaps more dangerous flaw of stringing is the error evident in the process. Placing the strings at accurate angles and precisely along the indicated path can be difficult. Subjectivity can easily be

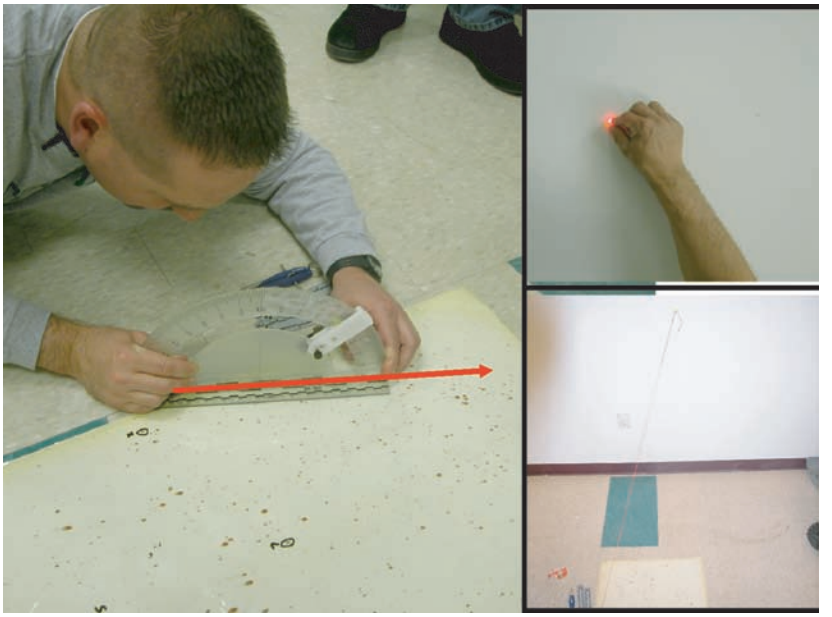


Figure 8.39 The use of a laser protractor for stringing a scene. The protractor is aligned to the directional angle and set at the indicated impact angle. The end of the string is then attached to the point where the laser dot appears.

introduced into the process, with analysts tweaking their strings to make them look more precise. The use of a laser protractor certainly helps eliminate some of the problems associated with this issue.

In actual casework, any stringing effort that results in an extremely tight convergence of the individual strings should be considered suspect. In our experience, it is highly improbable the resulting strings would cross so precisely, given the inherent limitations of the process. The likelihood of obtaining a pinpoint position with strings is low to begin with. As we increase the number of stains and strings considered, that possibility decreases dramatically.

Figure 8.40 A student stringing exercise. The more strings that are added to the effort, the more effectively an area of convergence is identified.

A final drawback associated with stringing is the inherent risk associated with the process. In order to string, the analysts must get in close proximity to the stained surfaces. They have to interact physically with these surfaces, putting them in repeated proximity to blood and all of its associated biohazards. Even with appropriate countermeasures (e.g., protective clothing) there is always a risk to the analyst. The use of forensic software as we will describe in this chapter effectively reduces this risk.

Forensic Software Applications

Computer software advancements over the past few years suggest that we replace stringing in its entirety. These programs offer the analyst an efficient and relatively effective method of analyzing spatter patterns for area of origin information. A program called Trajectories was one of the first true "analysis" programs. Developed by Dr. Alfred Carter of Carleton University in 1987, it allowed the analyst to evaluate area of origin using crime scene data.

Dr. Carter improved upon Trajectories and eventually released it through Forensic Computing of Ottawa (FCO) as BackTrack®, a full-function program that allowed for area of origin calculations on vertical surfaces.[6] BackTrack employed actual flight path (parabola) calculations, which incorporated estimates of blood droplet volume, and gravity and air resistance factors.

Shortly after BackTrack's release, FCO released another program, BackTrack/Strings®.[7] FCO scaled down this version somewhat, changing the manner in which it handles the area of origin algorithm. It has all the primary functions of BackTrack, but utilizes a strings approach in determining flight paths in lieu of the parabola approach.

In running BackTrack/Strings, the analyst measures the stains present at the crime scene. This includes identifying the stain's coordinate position, width and length, and the gamma angle (a term synonymous with directional angle). Once entered for each stain, the analyst moves to a top view and chooses paths that converge. The chosen lines of convergence provide the computer with an averaged CPx and CPy (a top view convergence point in the X and Y plane).

The analyst then moves to the side view and, again considering the paths, chooses an appropriate CPz. Generally, the analyst does this by lowering the cursor and choosing a point below the paths of the computer's virtual strings. Once chosen, the analyst saves these convergence points and the software creates a graphical representation of the probable area of origin.

Subsequent to Bactrack/Strings, Dr. Carter produced two additional programs that work in conjunction with each other. The first was Backtrack Images.[8] Using photographs of stains, Images allows the analyst to identify the gamma and impact angle for each stain on the computer.

To use Images, the analyst documents the stains in question at the scene with a digital camera. Before documentation, two pieces of information must be included in the photograph. First, the analyst must draw a plumb line onto the surface so that Images can establish a gamma angle. The analyst then inserts a small readable reference scale, which Images uses to determine actual scale of the photograph (see Figure 8.41). Additionally, each stain must be documented in terms of its XYZ position on the wall or surface. Although the method might sound difficult, it is actually extremely efficient once the analyst becomes accustomed to it. The analyst chooses the stains, marks and annotates each, measures the XYZ coordinates, introduces small adhesive scales by each, and then draws the plumb line. Then the photos are taken. Even with a large pattern, where the number of stains chosen for evaluation exceeds 20 or more, the entire process can be accomplished on scene in under 30 min.

The Images program allows the analyst to compare the image to a virtual ellipse on the computer screen. The analyst graphically adjusts the virtual ellipse to fit the stain photo. Once completed, the software determines the angle from the ellipse measurements. All

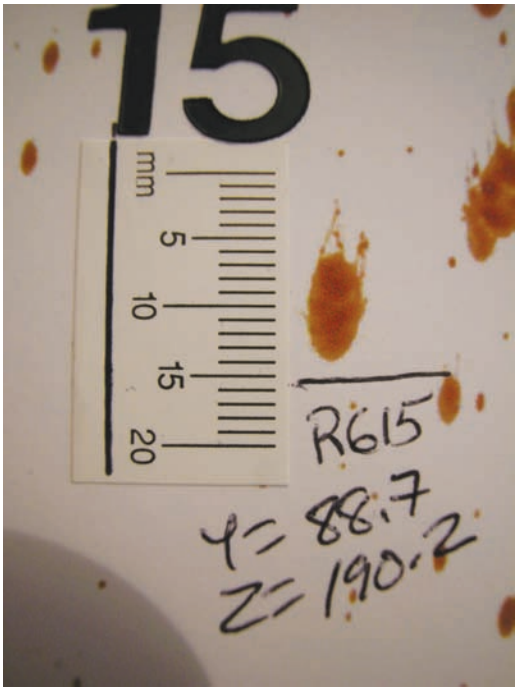


Figure 8.41 Using software such as Backtrack Images, the analyst must capture certain on-scene information. A small scale is included, as well as the position of the stain (YZ in this instance) to allow the software to accurately place the stain in the scene and establish its measurements. The analyst then draws a plumb line on the scale adjacent to the stain, which allows the software to identify the gamma (directional) angle. Note that the stain is marked with a stain number, so each photo is easily distinguished from another.

of the information derived for each stain is then stored in a database. This information is brought over to another program, Backtrack/Win, where the area of origin can more effectively be evaluated.

Backtrack/Win[9] takes input either from Images or information gathered directly by the analyst. Following a similar routine as found in previous Backtrack products, it determines the various convergence points and area of origin and then creates printouts demonstrating this information. Figure 8.42 is a printout of a top view created by Backtrack/Win. The small cross represents the established convergence point for the top view. Figure 8.43 is a side view printout of the same stain pattern. Once again, the small cross represents the side view convergence point and with both convergence calculations complete, the display textually lists the area of origin in the upper right corner.

Beyond any added efficiency and accuracy that these programs offer, they effectively reduce the risks associated with biohazards at the crime scene. Any decision to purchase such programs by a crime scene supervisor is better based on the risk management issues than on any claim of greater precision by computer programs.

How Many Stains Are Enough?

Area of origin analysis requires the analyst to locate and choose a number of "well-formed" stains in the pattern, but how many stains are enough? This is a difficult question to answer

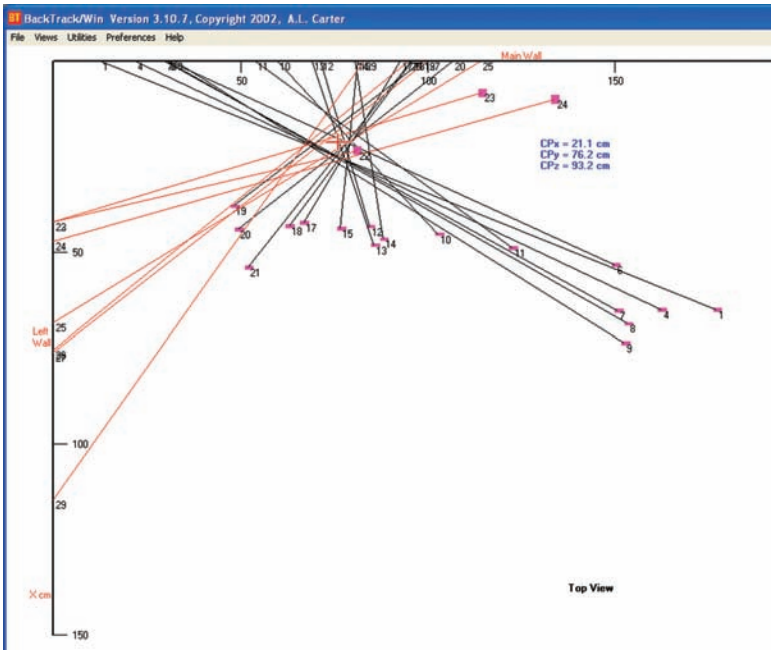


Figure 8.42 A Backtrack/Win top view screen. This view identifies the overhead point of convergence (XY) for a group of spatter stains. The small cross is the mathematical mean for all of the points of convergence. The calculated position for the various convergences is annotated in the text at the top right.

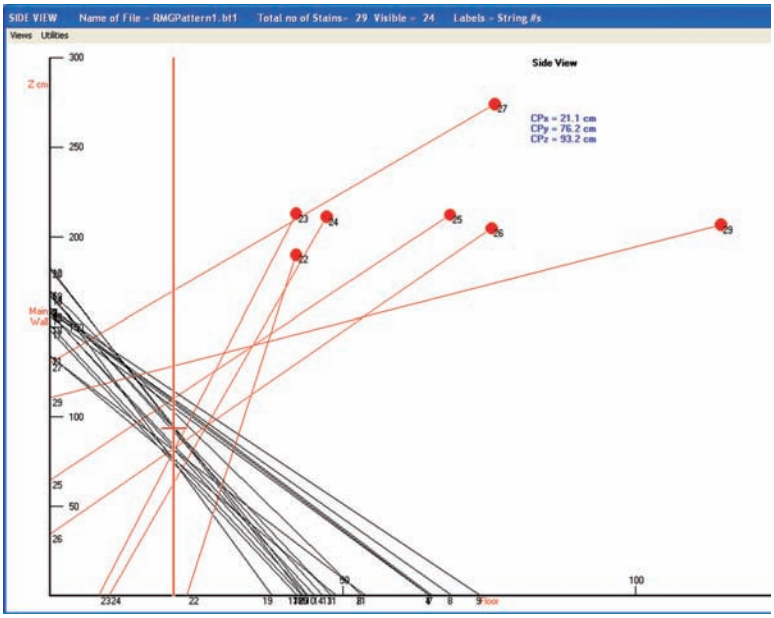


Figure 8.43 A side-view screen from Backtrack/Win. In this view, the small line that crosses the extended line identifies the convergence point of the side view (ZX).

outside of a specific context. The answer will depend in great part on the nature of the pattern. Is the pattern radiating broadly or tightly? How many well-formed stains are present? Is there an indication of two impacts? All of these issues may require the analyst to conduct area of origin analysis with fewer stains or suggest inclusion of a greater number of stains. It would certainly be inappropriate to evaluate only two or three stains when other well-formed stains were present in the pattern. The authors would suggest the minimum number of stains used (presuming no other well-formed stains are available in the pattern) be no less than four.

Automation Efficiency or Precision — An Important Distinction

We hope it is evident that forensic software programs allow the analyst to locate more efficiently the area of origin of a given event. The computer handles the data and calculations in a precise manner, eliminating human math errors and some of the subjectivity inherent in the stringing and stubby pencil routines. What is not evident is whether a more efficient mathematical process means a more precise definition of the true area of origin. Your authors would argue that it does not.

In a classic stringing technique, one usually limits the area of origin to somewhere between the size of a tennis ball up to a soccer ball. Rarely has the need existed to define this location further, particularly by trying to define an absolute point. Using the graphing technique described, one also identifies a generalized area in which the various stain paths appear to converge. This limitation in precision really does not matter because the natures of the events that create spatter are themselves dynamic and probably cannot be pinpointed in 99% of all situations. They occur over a given area involved in the event.

Granted, in some instances, the movement involved may only be a few inches in area, but that is distinct when compared to a precise point in space. Events rarely, if ever, occur at a precise XYZ coordinate point. Additionally, one must consider that wounds are often jagged and are certainly not defined by precise points. Thus, trying to define an absolute XYZ coordinate as an area of origin is really a moot issue. For the analyst to state that an event occurred at a precise point in space is almost ludicrous.

Unlike the old stringing technique, however, the computer provides us with a very precise point in three-dimensional space. The software programs graphically depict this point and then give an absolute XYZ point in text. Having failed to read the software documentation and lacking an understanding of basic blood droplet dynamics, someone evaluating this information could easily assume the computer had narrowed the event down to this absolute location. As analysts, we recognize these points as idealized and based on the averages contained in the data. They do not place the event in an absolute location with absolute precision.

Can we more easily compute area of origin using computers? Yes. Are computers more absolute in their accuracy of defining the event? No. Mere placement of a decimal point in a mathematical calculation will not eliminate the level of uncertainty that will always exist in these situations.

Limitations in Area of Origin Evaluations

Using straight-line geometry and trigonometric functions allows the analyst to identify the probable area of origin for the stains. Although generally accurate, it should be evident

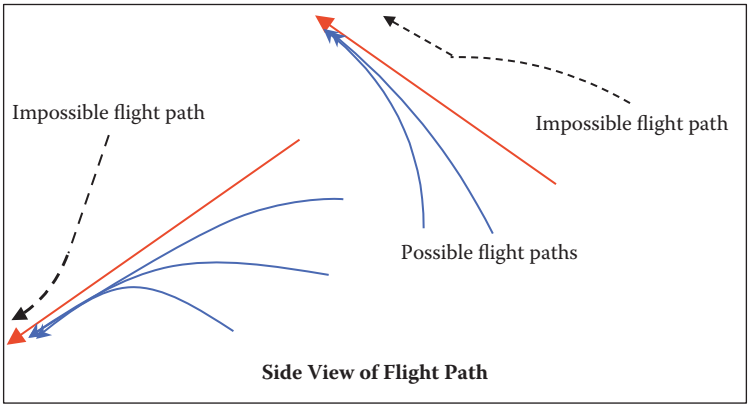


Figure 8.44 The angle of impact establishes an absolute limit for the droplet's origin. For instance, a droplet can originate at some point under the angle of impact. As it follows its path, gravity affects the path making it steeper and causing the droplet to strike at the angle indicated by the stain. What cannot happen is for the droplet to alter its path on its own, defying gravity's effects, thus striking the target from a point above the indicated angle of impact.

to the reader that both methods make a major assumption. Both assume the droplets involved travel in straight-line trajectories. Unfortunately, this is not true, as both gravity and air resistance affect the droplet.

As long as the analyst recognizes this inherent limitation, the two methods are both functional and useful. They do not define the droplet's flight paths absolutely. However, they do place specific limits on that path. Consider Figure 8.44. The impact angle for each droplet in effect sets a limit of possible and impossible flight paths.

A critical consideration in area of origin determinations is the difference between evaluating horizontal and vertical targets. We raised this issue earlier in the chapter and it is imperative that we fully explain these concerns. When we look at a spatter pattern from a top view (looking at the stains' directionality) on a horizontal surface, gravity and air resistance have no affect. The top view of a pattern on a vertical surface is quite different. On a vertical surface, a top view of the pattern is the vertical plane and both gravity and air resistance affect the flight path and the resulting directional angle.

There are three general situations we might encounter in a vertical surface target. The droplets may still be accelerating because of the impact and traveling in generally straight lines. The droplets may be losing acceleration or the droplets may have lost their initial acceleration and are falling out of their parabolas.

Figure 8.45 demonstrates the first circumstance. In this instance, the droplets are still accelerating and their flight paths are straight. When they impact the vertical surface, the impact angle and directional angle, and thus the area of origin defined by this information, are true representations of their origin.

Figure 8.46 demonstrates the second circumstance. In this instance, the droplets are losing their initial acceleration because of the effect of both gravity and air resistance. Their flight paths in the vertical plane are affected by this and they become arced. The information defined by the resulting stains' directionality and impact angle still leads us back to an area. However, because of the change in the flight path, the strings and actual flight path are beginning to diverge.

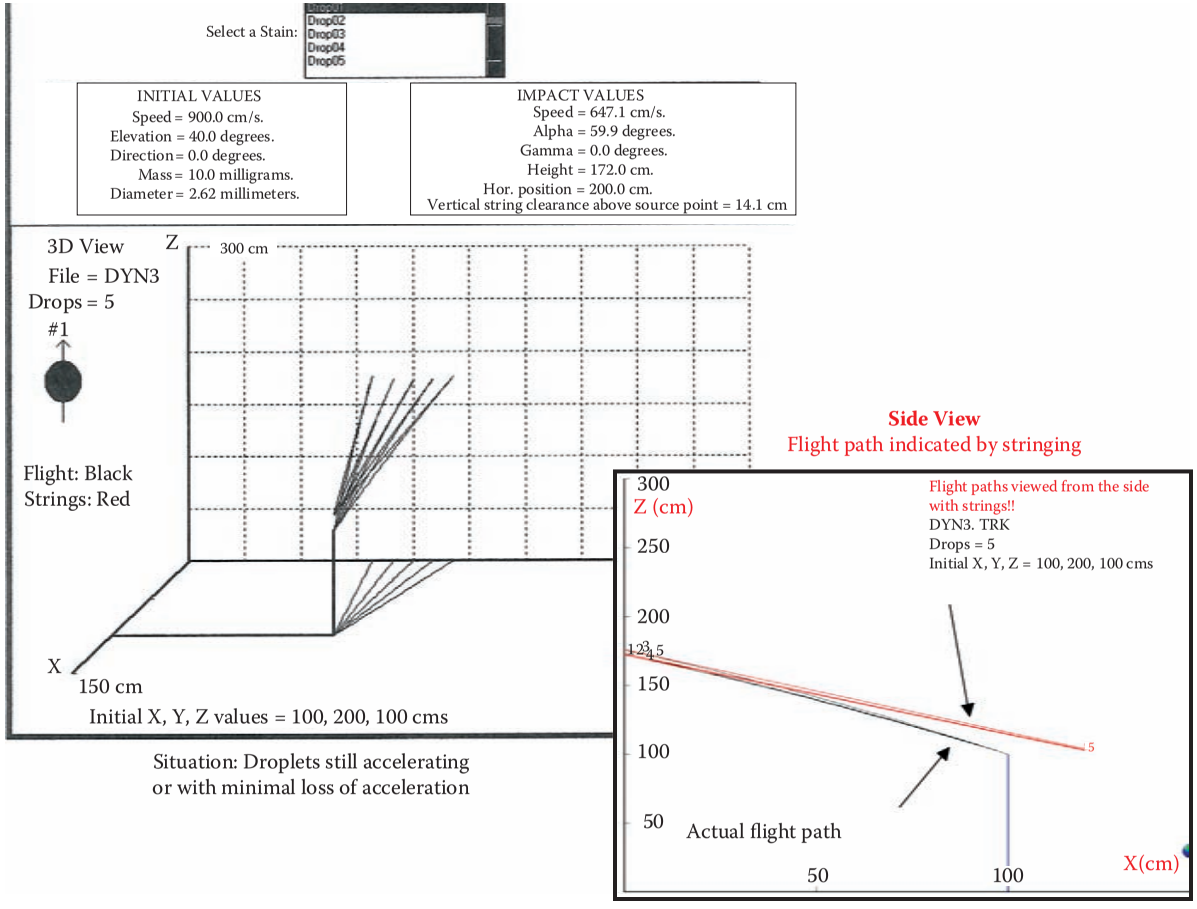


Figure 8.45 In dealing with a vertical target and the effect of gravity and air resistance, the best-case scenario is one in which the droplets have not lost acceleration. In this instance, the strings are a good representation of the actual flight paths.

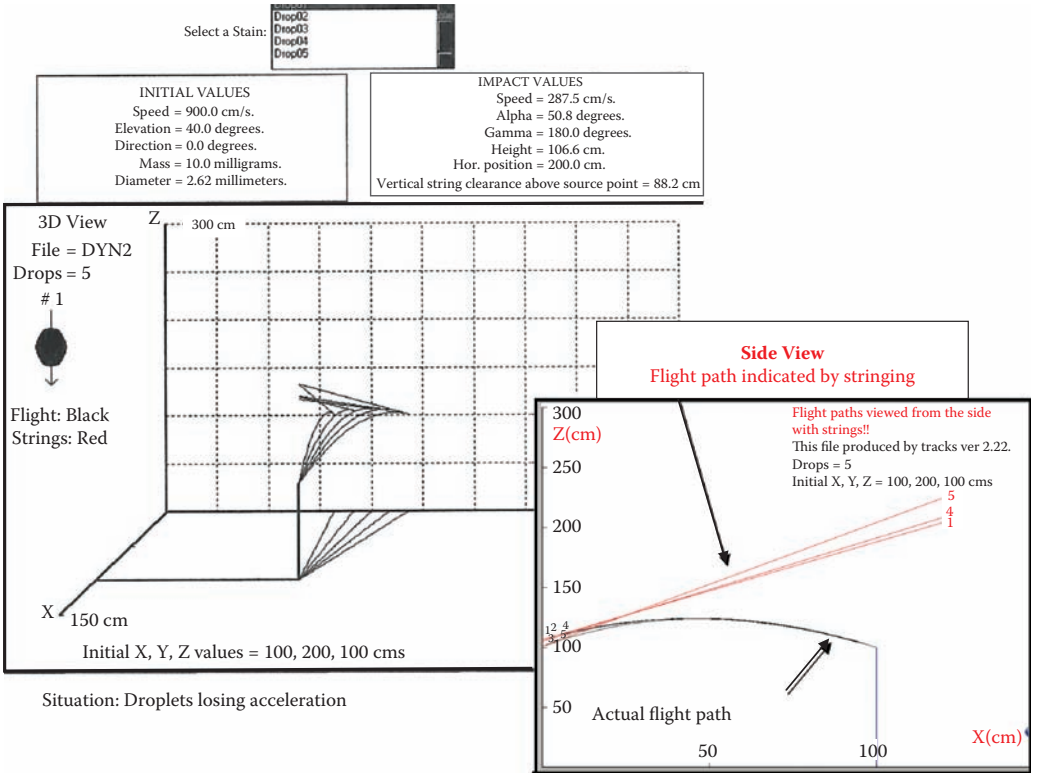


Figure 8.46 In dealing with a vertical target and the effect of gravity and air resistance, it is also possible the droplets will have lost some acceleration. As they do, the difference between the actual flight path and strings will begin to increase.

Figure 8.47 demonstrates the worst possible situation. In this instance, the droplets have lost their initial acceleration from the impact. They are closing in on their terminal velocity and are following steep downward paths. The resulting string paths suggested by the stains will reflect this path alteration. The stains will have directional angles showing they were moving toward the floor and the impact angles will reflect sharp angles into the wall. The divergence between the virtual strings and the actual flight paths is significant. Any attempt at defining the area of origin with such stains will suggest an origin near the ceiling.

The more gravity pulls the droplets from their flight path, the more this effect is evident. This alteration of the impact and gamma angle on vertical surfaces will effectively move the indicated area of origin in and upward. It is important to note that not every pattern that has downward moving droplets is affected by this issue. Is it possible for a pattern to be directed downward onto a vertical surface in close proximity to that surface? Of course it is, and the droplets would still have acceleration and the stains would still provide functional directional and impact angle information (see Figure 8.48). Carefully considering the radiating effect of the pattern may allow the analyst to recognize the difference between these two distinct situations.

Even in the worst situation, the information reflected in the area of origin analysis still offers some valid information. If we apply what is referred to as the umbrella effect, any area of origin evaluation sets parameters of possible and impossible flight paths. For example, a droplet traveling downward toward the wall at an angle of 60° may have originated at some

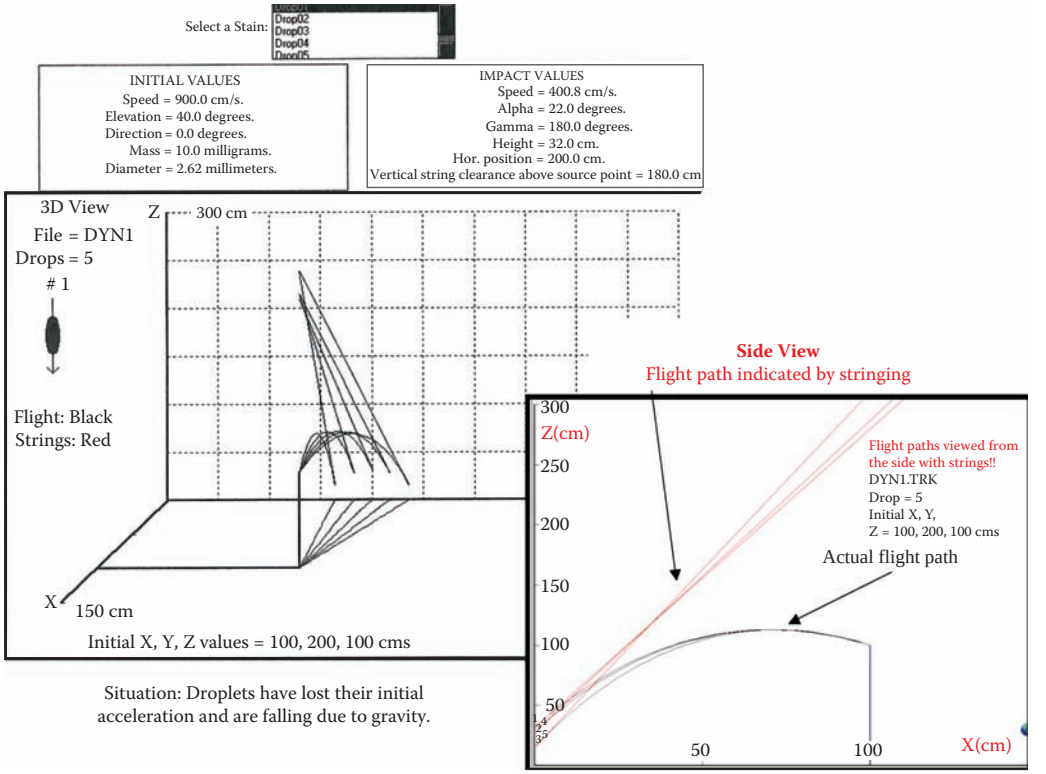


Figure 8.47 In the worst case on a vertical target, the drops have lost acceleration and are falling with gravity. The strings suggested by the impact angles will literally point to the ceiling.

point behind the indicated angle of impact. That is, it may have been projected 80° toward the wall. As the droplet slows in flight, its flight path begins to angle downward into the ground, eventually striking the target at the more acute angle of 60°. What cannot happen, however, is for the droplet to gain momentum on its own. Having been projected toward the target at 40°, the droplet cannot strike at a less acute angle (e.g., 60°). Refer to Figure 8.44.

The limitations involved in area of origin evaluations demand that we always use caution in considering the results. This is particularly true for those situations involving vertical targets and dual impacts. The indicated area of origin sets an absolute upper limit for the event based on the umbrella effect, but cannot always exclude the event from having occurred at a point beneath the indicated area of origin. The ability to make an exclusion is situation-driven, depending upon the number of stains available and the nature and dispersion of the stains.

Summary

Having defined the point from which a group of stains converge or originate, how does the analyst use this information? Lacking specific knowledge of the crime, this process helps identify the general location at which some type of impact occurred. This is particularly useful in placing the subject or victim at specific locations within the scene. By differentiating two distinct points of origin from what appears to be a single spatter pattern, it also identifies an additional impact that was not otherwise evident.

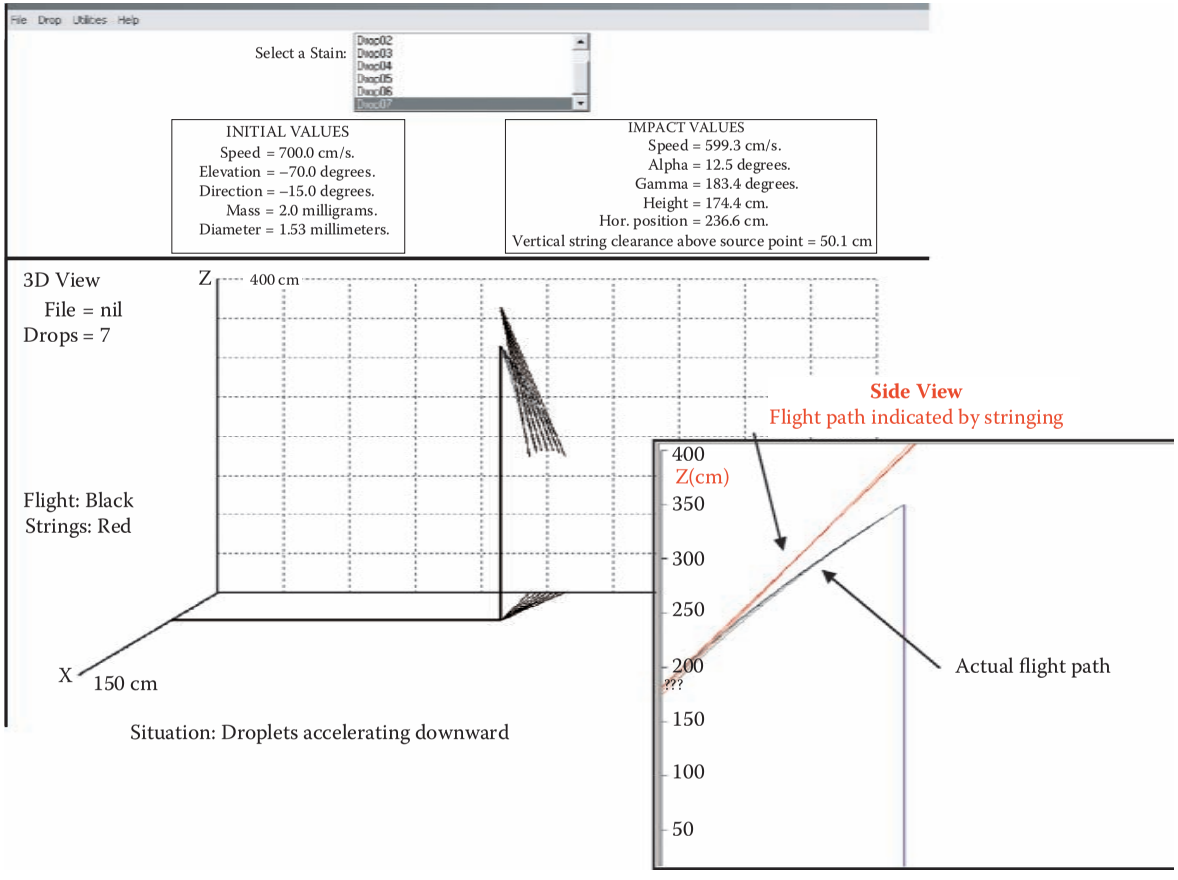


Figure 8.48 The fact that drops are moving downward on a vertical target in and of itself does not establish that they are of no value. It is possible that a downward ejection will occur in which the droplets are still moving with their initial acceleration. Recognizing this situation, as compared to drops falling out of their parabola, demands consideration of the radiating effect in the pattern.

Primarily, we will use this information to refute or corroborate claims by those involved in the incident. Imagine a situation in which a subject claims self-defense and that all blows delivered to the victim were struck as the victim made a standing attack against the subject. In evaluating the area of origin, let us assume we find evidence of blows delivered from a point low on the ground. Finding this, we have physical proof with which to dismiss, at least in part, the subject's statement.

Area of origin determinations are not always necessary, but they can be very illuminating. As discussed, the analyst can choose to view the stains considering only directionality. This simply identifies a point of convergence on a single plane.

A second, more functional, approach demands the analyst determine the impact angles of the individual droplets involved. This angle is determined using the ratio of the length of a stain to its width. The impact angle, when combined with point of convergence, defines the approximate point in space from which the droplets originated.

In the past, we generally used the stringing or graphing methods to identify this point. Automation advances now allow us to complete the analysis in a more refined and efficient fashion. Even with such advancements, the analyst still recognizes that any area of origin estimation is exactly that, *an estimation*.

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Evaluating Impact Spatter Bloodstains

9

One of the primary functions of the analyst is to classify the specific stains and patterns found. Once categorized, the analyst then attempts to identify the underlying nature of the event causing the pattern. An important pattern found at many crime scenes is the impact spatter pattern. Impact spatter is a radiating pattern resulting from some application of force to a blood source. As definitive as this is, unfortunately there is some disagreement on how to differentiate impact spatter. What is generally agreed upon is that impact patterns often help us understand the orientation of the event and perhaps the general nature of the force involved.

Methods of Description

The first concern with the pattern is to categorize or describe it. What does it look like? What criteria does it meet? These are the questions most commonly asked. One approach to categorizing spatter is based on impact velocities. As a result of early references in bloodstain analysis, bloodstains routinely became categorized into three velocity groupings. These categories refer to the nature of the impact causing the stain and are called low, medium, and high.[1] Not everyone agrees with this grouping, but used as intended the categories were, and are, adequate.

In a descriptive sense, low-velocity stains are those of relatively large size. The limited amount of force applied to the blood produces large drops. The resulting stains are generally 4 mm or larger in diameter.

Low-velocity stains are reported to result from normal gravitational forces or actions up to a force or energy of 5 ft/s. These stains are typical of venous bleeding in which the individual is injured and natural blood flow subsequently falls to the floor or from blood dripping from bloodied objects.

Medium-velocity impact spatter (MVIS) is a pattern in which the preponderant stain size is generally 1 to 4 mm in diameter, and is created as a result of some application of force.[2] Historically, these stains are reported as resulting from a force of up to 25 ft/s. The droplets produced are smaller than that found in low-velocity events, thus the resulting stains are smaller as well. This increased break-up (the smaller drops) is due to the increase in the force applied to the event. Figure 9.1 and Figure 9.2 depict two medium-velocity spatter patterns.

High-velocity impact spatter (HVIS) is a pattern in which the preponderant stain size is 1 mm or less in diameter. These stains are reported as being associated with a force in excess of 100 ft/s.[3] High velocity patterns often include smaller sub-millimeter sized stains as well; descriptively, such stains are often referred to as mist-like (see Figure 9.3).

There are several problems associated with the "velocity" method of description. The first relates to these reported "velocity" figures. The figures of 5 ft/s, 25 ft/s, and 100 ft/s, and their association to a specific size of spatter have never been fully explained, nor has the foundation of such an association been defined. A second more problematic issue becomes

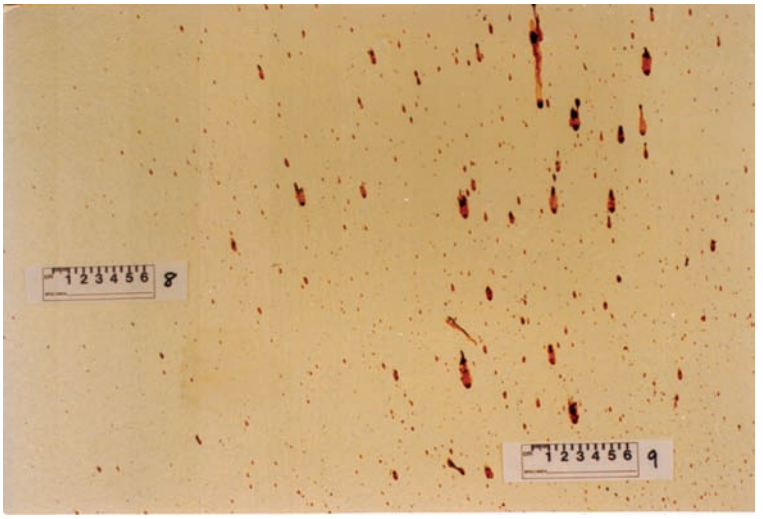

Figure 9.1 An example of a stain meeting the "medium velocity" definition. This pattern was produced by a blunt force impact to the victim. (Photograph courtesy of Toby Wolson, MS Miami-Dade Police Department, Miami, FL. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

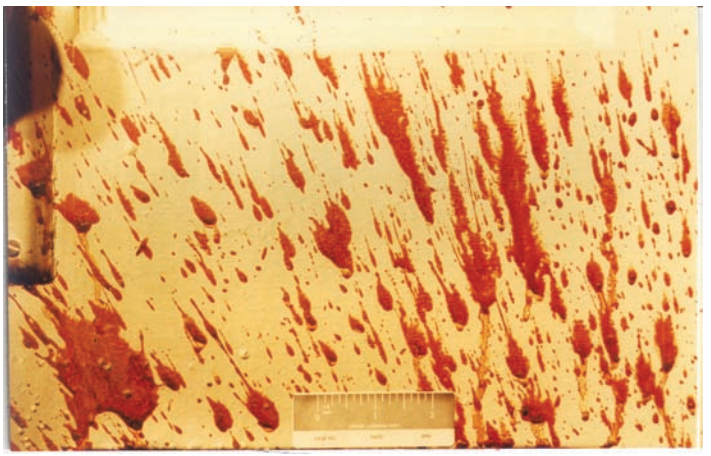

Figure 9.2 Another example of impact spatter meeting the "medium velocity" definition. These stains resulted from a blunt force beating to the victim. The stains were then altered somewhat by a fire set to conceal the crime. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, OR.)

evident when discussing stains among analysts and lawyers. Quite often, when using a velocity label as a description, others assume it to mean a definition of the event. That is, by classifying something as a high-velocity incident, they believe the analyst means the underlying event must be a gunshot. This is not a valid association. A third issue related to velocity labels is that many analysts who use these terms tend to set absolute ranges of spatter size for the so-called low-, medium-, and high-velocity spatter patterns. Thus, a medium velocity pattern will consist of 1 to 4 mm sized stains to the exclusion of any other size. Analysts generally quote the work of MacDonell and Bialousz as a basis for such ranges. In fact, there

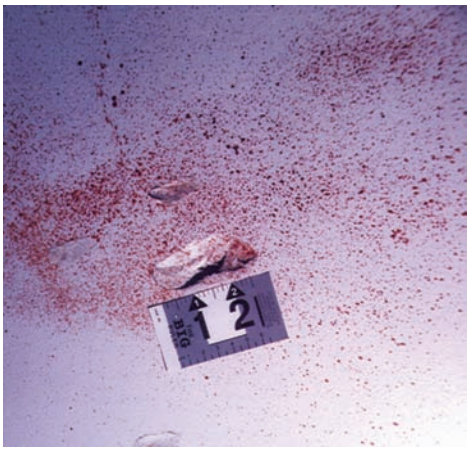

Figure 9.3 An example of a stain meeting the "high velocity" definition. This pattern was produced by blows to the head of a victim with a baseball bat, which demonstrates the concern of associating specific velocity patterns to specific events. High velocity is certainly encountered in gunshot events, but is not limited to them.

are no absolute size ranges evident in the writings of either MacDonell or Bialousz. Nor is it clear if they intended that absolute parameters were in force based on their experiments.

It is also evident that MacDonell and Bialousz never intended to assign event status to "medium velocity" or "high velocity" labels, but because of their work, analysts often make such associations. Can a general association of these patterns to different mechanisms be established? Yes to a point, but these patterns are not in and of themselves defined as being *only* the result of such events. MacDonell and Bialousz simply provided a basic method of definition or description for spatter patterns, and generally associated certain events with the patterns. What remains evident in their work is the correlation that as we increase the amount of force applied to the blood source, we see a corresponding decrease in spatter size.

There is one important note regarding the velocity label. Remember that the speed (i.e., 5 and 25 ft/s) refers to the velocity of the wounding agent (the force applied) and not to the velocity of the blood in flight. This issue is often confused.

An alternative to the velocity label approach is the descriptive label. Because of their observations, Parker et al. chose to refer to spatter patterns based on descriptive labels. Their intent was to describe the stain based purely on the physical characteristics the analyst observed. Parker et al. classified these groupings as either "fine" or "coarse".[6] Their fine category included spatter with diameters of 3 mm or less, while coarse spatter were those stains with diameters of over 3 mm.[7] The approach was not radically different from MacDonell's; it simply did not interject any association to the underlying event.

Another advocate of a descriptive approach was Judy Bunker. Bunker did not adopt Parker's terminology, but she taught students to identify all patterns present, documenting each with a detailed physical description based on observable characteristics. This purely descriptive approach has definite merit. Bunker's intent was for the analyst to first observe the stain and make conclusions about it later.[8] This method also eliminates some disparity evident with velocity labeling as it is used today.

It is not the intent of the authors to attack the velocity description, but this classification system has limitations. When used to describe and categorize spatter of specific sizes it works fine in most instances. Its limitations come from assigning absolute demarcation

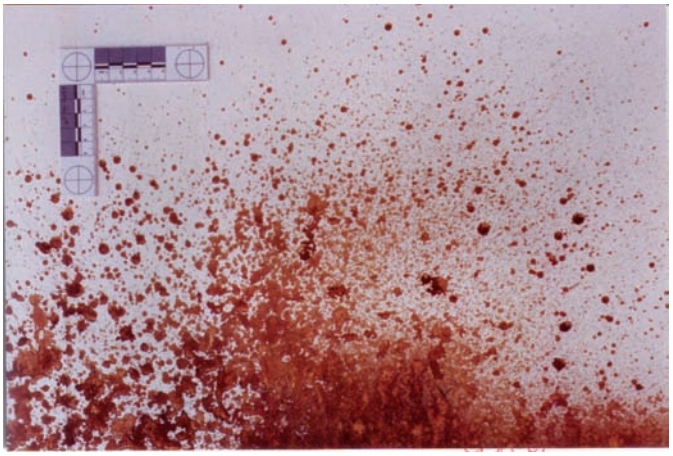

Figure 9.4 The pattern produced when a flash-bang device was activated next to a small pool of blood. The target was in a vertical position. (Photograph courtesy of Tom J. Griffin.)

points (e.g., 5 to 25 ft/s) for which known exceptions exist and associating the label to specific events to the exclusion of others.

Whatever method of description one chooses to use, the analyst's first concern is in realizing that descriptions of patterns should be nothing more than descriptions. Any description should define only the observable characteristics evident in the pattern.

Having said this, we can still make some general statements regarding the events that are typically associated with spatter. Large spatter like medium-velocity or coarse spatter are typical of situations in which blunt trauma is the cause of the bleeding injuries. High-velocity or fine spatter is more typical of gunshot injuries, explosive force, or high-speed machinery. Although not common to most crime scenes, examples of these small spatters can be found in situations involving explosions (see Figure 9.4). The reader should consider these statements as a general guideline and nothing more.

Understanding the Concept of Preponderant Stain Size

When using the descriptive label, at some point the analyst must evaluate the given impact pattern and define it in some fashion. Unfortunately, within any given pattern there may be a wide range of individual spatter sizes.

Imagine a pattern of 15 individual spatter stains with the following sizes:

Individual Stain Size	# of Stains
0.25 – 1 mm	3
1.1 – 4 mm	10
4.1 – 6 mm	2

If the analyst chose to use the smallest stain (e.g., 0.25 mm) the pattern might be categorized as fine or high velocity. On the other hand, if the analyst chose to use the largest stain present (e.g., 6 mm) the stain might be categorized as course or low velocity.

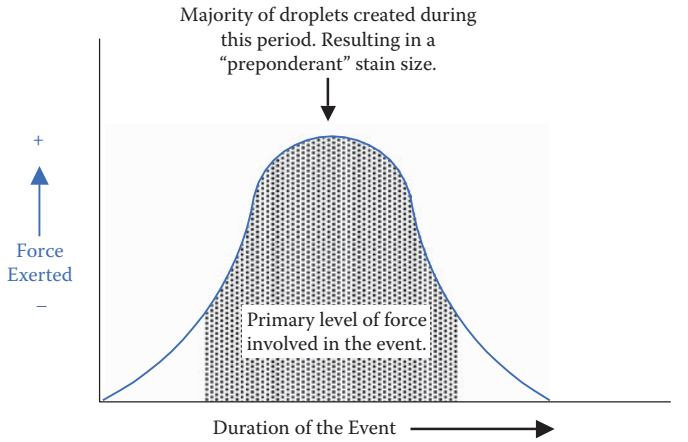

Figure 9.5 The shadowed area represents the level of force most evident in the event. The predominant spatter present in the pattern will result from this level of force, but as the force builds, peaks, and then wanes, other spatter of varying sizes will be produced as well. Thus, in any spatter pattern, smaller and larger spatter are likely to be present.

To properly understand a pattern, the analyst looks at the preponderant individual stain size within it. In this instance that happens to be the 1 to 4 mm size (i.e., 66% of the pattern fits this range). Using a velocity label, that would identify the pattern as "medium velocity."

It is important to understand when making this decision that "perfect" impacts do not exist. There are no perfect patterns. The size range evident in any pattern is often great, and there may not be a clear demarcation for the preponderant stain size.

This lack of a demarcation is the result of the dynamic nature of the impact itself. We know a single impact will act upon a blood source in different fashions during the milliseconds in which the event occurs. As the action unfolds the force is applied, the energy or pressure exerted by the force builds, it reaches a peak, it then declines. There is rarely a perfect impact in which force is applied cleanly, evenly, and in the same fashion across the entire blood source. Across the continuum of time it takes the event to occur, the blood may be acted on quite differently (see Figure 9.5).

Droplets created when the force is at its predominant level (the shadowed area of Figure 9.5) represent the vast majority of droplets created by the action. These stains will likely reflect the "preponderant" stain size of the pattern and establish a macro view of the event or action. Stains created at the onset or end of the action may well be larger. Just the same, we may also find spatters much smaller than our preponderant stain size created when the force was at its absolute peak.

The analyst must decide which size of stain is the preponderant stain in the pattern, or report the overall range of size evident in the pattern. Most often, when deciding the preponderant stain size, analysts use an eyeball method. They simply evaluate the stain and pick the size that appears to be the most prevalent. We caution you to use care with such "eyeball" examinations. The process is not always accurate. This is particularly true when evaluating stains that contain hundreds of spatters, where the analyst tends to focus on the larger, easier-to-see stains.

In one instance known to us, an analyst claimed that a spatter pattern could neither be included nor excluded as resulting from back spatter. He naturally labeled back spatter

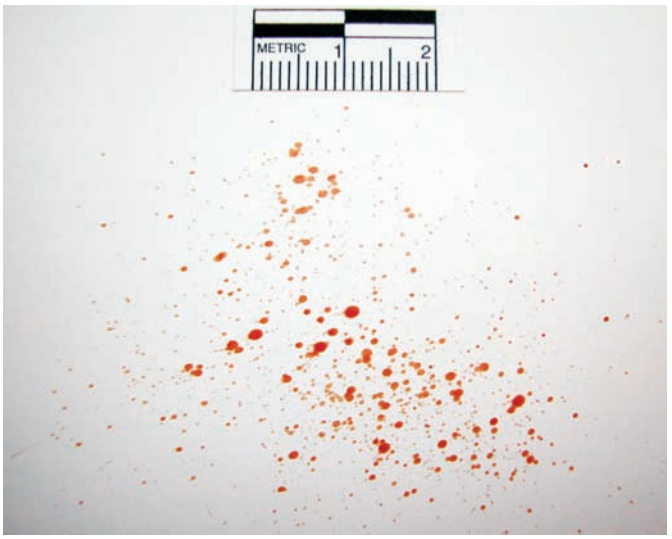

Figure 9.6 An example of the difficulty present in the velocity label description. This spatter resulted from a slap to a single drop of blood, which we would generally define as blunt force. However, it produces a fine spatter that is well within the parameters of the "high velocity" definition. Velocity definitions should always be attributed to the pattern based on stain characteristics, with no assumptions regarding the event.

as high velocity, but then claimed the pattern in question matched a slap-type event.* He chose to label this slap as a medium-velocity event. The pattern in question included 160 individual stains that were evaluated and ranged in size as follows:

Individual Stain Size	Number (%) of Stains
0.25 – 0.49 mm	67 (41%)
0.5 – 0.99 mm	70 (45%)
1 mm or greater	23 (14%)

For comparison, slap-drop standards were created under the conditions claimed by this analyst. The scene pattern and slap-drop standard when evaluated using the "eyeball" examination appeared quite similar, but when evaluated in depth they showed marked differences. The "medium-velocity" slap actually created a preponderant stain size much smaller than that found in the questioned pattern or a back spatter standard (see Figure 9.6).

This example demonstrates some of the difficulties encountered when categorizing spatter patterns. The slap pattern when considered in detail was not consistent with the questioned pattern, yet based on a limited eyeball examination it appeared to be consistent. Additionally, the categorization of a questioned stain as medium velocity, 86% of which is less than 1 mm in size, either fails to consider the whole pattern concept or rewrites the underlying definitions. Such contradictory issues are probably more common than we might imagine, particularly when the velocity labels are in use. They demand that we carefully consider what characteristics lead us to our conclusions regarding spatter patterns.

* An event in which a small volume of blood was slapped by several fingers.

This is not to say that analysts must measure every stain to make a call on a pattern, but they must ensure that the sampling used for categorization is sufficient. Once again, we would prefer the decisions to include or exclude a pattern as being consistent with something be based on a clear, specific, and verifiable characteristic combined with a holistic approach.

Impact Droplet Size

As previously discussed, the size of a spatter stain is a basic consideration that at least points us in the general direction of defining the nature of the force involved in creating the stain. For drops projected into the scene, the volume of blood present in a droplet is the primary determining factor for the subsequent stain size. What forces are required to cause subdivision of a blood source to create droplets? As MacDonell, Parker, and most other researchers discovered, blood and stable blood drops do not spontaneously degenerate from one volume to another.

The energy transferred by an impact to the mass of blood causes the blood to break up at the source. As described in Chapter 5, the blood mass is ejected along any avenue of escape; it cannot be compressed. As it does this, spine and sheet-like structures are created that shear into smaller masses. These smaller masses of blood stabilize through the affect of surface tension creating individual stable drops of spatter. Once these masses have undergone this ejection and become stable droplets, no further force beyond gravity and air resistance are present to affect them. This is also true of the stable droplets in free flight. To further divide and become smaller droplets, some force must act on them. Air resistance and gravity certainly affect the flight path of these droplets, but will not break up stable drops into smaller droplets.

Once set in motion by an impact, no spontaneous subdivision will occur, as it is unlikely droplets will collide in flight.[12] The force of impact almost singularly defines the drop size, which establishes the stain size we ultimately see.

As one might expect, based on the size of impact spatter stains, impacts result in significantly smaller droplets than those resulting from drips and similar actions. We have found impact droplet diameters of 2 mm and smaller.[13] Remember, this is the actual droplet in flight, not the resulting stains. Droplets of this size have volumes of .005 ml or less.

This issue of the droplet's size is significant in our consideration of impact spatter for one reason. As we examined in prior chapters, the smaller the droplet, the quicker it attains and holds a true spherical shape. As a result of the very small droplet diameters found in impact spatter events, considerations in determining impact angles and defining the area where the impact occurred are generally reliable. At the source of the impact, we may see major droplet oscillations or unstable spine and sheet-like structures. These effects dissipate in less than 0.01 s. Away from the source of impact, the shape of small droplets in flight is not distinctly affected by other extraneous forces (e.g., wind or air currents) and they travel as near-perfect spheres.

Pattern Configuration and Dispersion in Impacts

Patterns associated with impact spatter have a radiating effect (see Figure 9.7). The center of this radiating pattern, as one would imagine, is the point where the impact occurred to

Figure 9.7 An example of the radiating effect observed in spatter patterns. The origin of the spatter is a point approximately 40 cm from the floor; note how the pattern expands outward the farther from this point it is deposited. This particular pattern was the result of a stomping death. (Photograph courtesy of Lt. William Gifford, Anchorage Police Department, Anchorage, AK.)

the blood source. The nature of how the pattern and individual stains within the pattern manifest themselves is dependent upon the relationship of the target with regard to the impact site.

For targets that lie parallel to the primary direction of force in the impact, we are likely to see elliptical stains within the pattern. On targets that lie perpendicular to the force, we will see the more spherical stains. Figure 9.8 provides a basic understanding of this relationship. The reader might also refer back to Chapter 5 for a discussion of how angle of impact affects the resulting stain shape.

As the patterns disperse or radiate out, it should also be evident that the closer a given target is to the impact site, the more stains one will find in any given area (e.g. per square inch or per square foot). As the droplets travel outward from the impact site, the distance between the stains increases as they follow their individual radiating paths.

This is best understood if we limit our discussion to stains in a single dimension. Using Figure 9.9, imagine an impact creating droplets. These droplets travel along a single plane, as represented in the figure. Based on the radiating effect, the droplets passing the cross-section labeled A are closer together than when passing B.

If we replace the cross-section with a vertical target and include a three-dimensional droplet pattern originating from the impact, the resulting stains would reflect this dispersion. Figure 9.10 and Figure 9.11 both show examples of this effect. The two patterns, produced by similar gunshot events, were each at different distances from the event. As a result, the closer target (Figure 9.10) shows a level of dispersion lower than that evident in the distant target (Figure 9.11).

This is not the only factor affecting the dispersion of droplets and their resulting stains. You will recall that air resistance has an inverse effect on droplets based on their size. Figure 9.12, a tracks model, demonstrates how droplet size can distinctly affect the distance it travels. All of the droplets in the model were projected at the same speed and

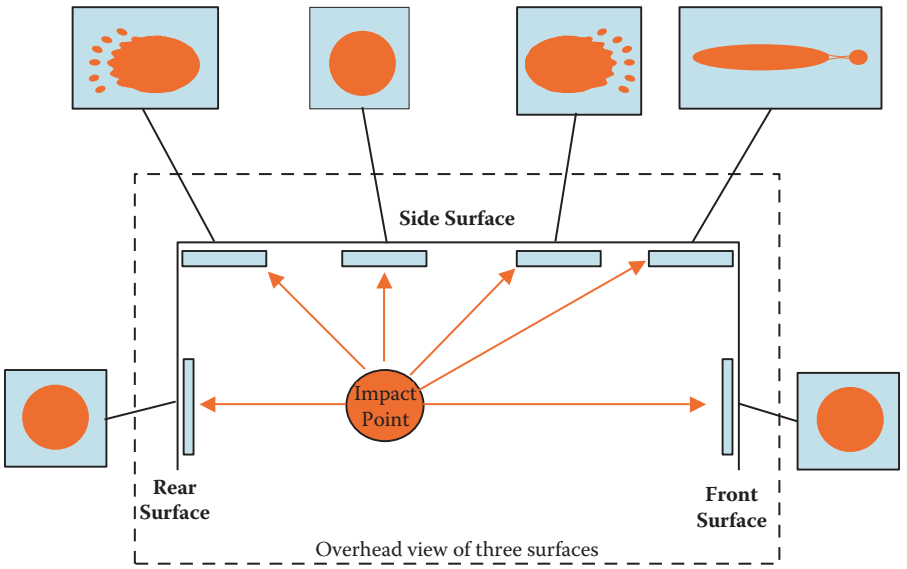

Figure 9.8 Stain shape and the relationship of the target to the impact. The stains we find in any given event may exist on any number of target surfaces. Thus, the position of the target in relation to the actual impact point will produce any number of different impact angles. By considering the resulting stain shapes, the stain positions, and the overall pattern configuration, we can distinguish the probable impact area.

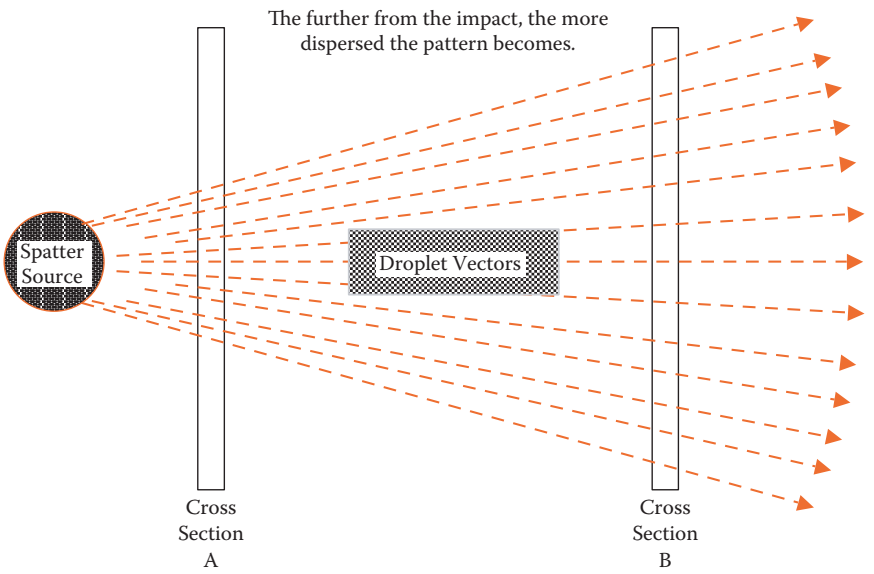

Figure 9.9 The radiating effect of a spatter pattern results in a higher level of dispersion in the stains farthest from the impact point. The figure is idealized and does not consider the effects of air resistance or individual droplet parabola. These factors also play a role in the apparent dispersion present in a pattern.

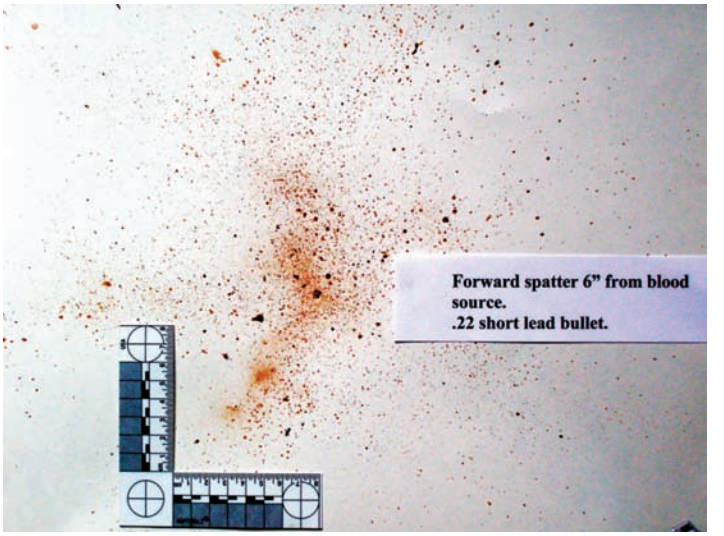

Figure 9.10 This pattern shows the level of dispersion in a gunshot event when the target was 6 in. from the blood source. Note the misting effect and the high number of stains present in the central area of the pattern. Compare this to the dispersion in Figure 9.11.

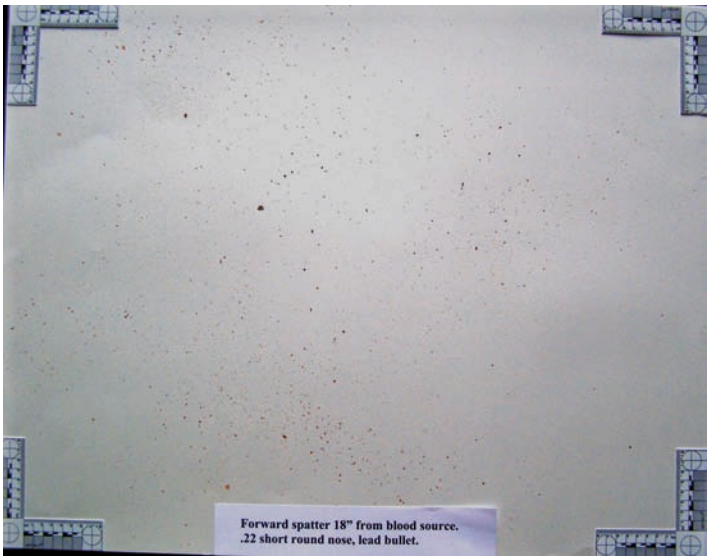

Figure 9.11 This pattern shows the level of dispersion present in a gunshot event when the target was 18 in. from the blood source. The pattern has a more dispersed nature with less of a misting effect.

along the same initial path. Because of their size, they followed distinctly different flight paths. Smaller droplets simply do not carry as far as larger droplets. This issue is a consideration when viewing the dispersion of patterns, particularly those associated with gunshot events.

Other factors that affect the overall pattern shape and dispersion are the manner in which the weapon contacts the impact site and the shape of the weapon. These factors may limit how the blood actually ejects from the impact site. The angle at which the weapon

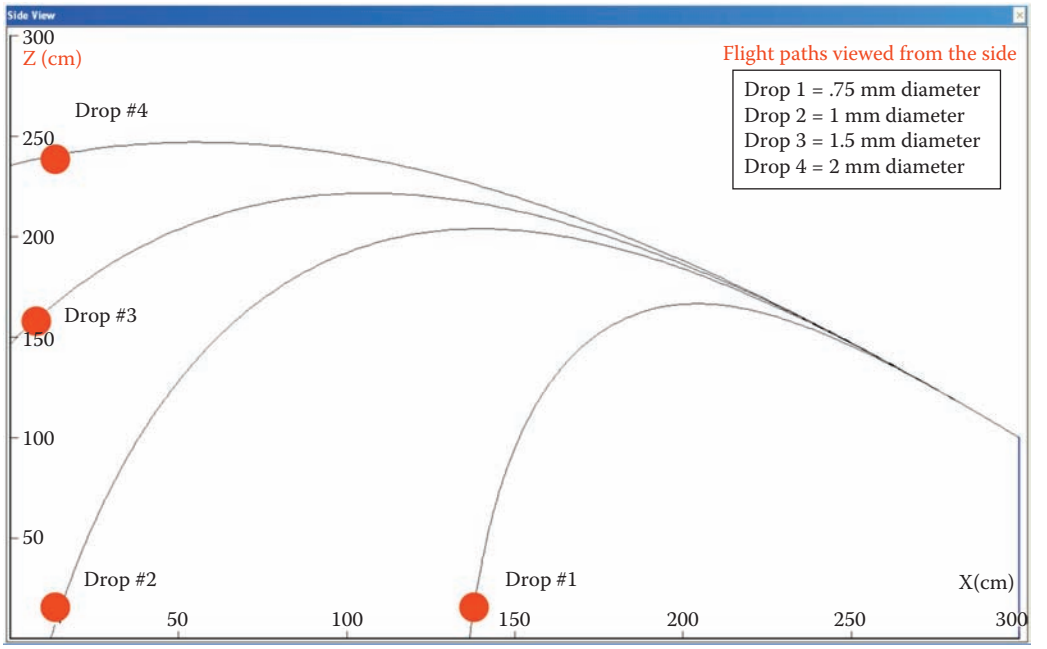

Figure 9.12 This Tracks model shows four droplets projected along the same initial path at the same speed. Note that all four follow different parabolas, with the smallest droplet (Droplet #1) traveling the shortest distance. This is primarily the result of the effect of air resistance on the droplet, which is inversely proportional to the size of the droplet.

strikes a surface or the nature of the weapon's shape or configuration may preclude blood ejecting in a symmetrical manner.

Because it is not evident based on empirical data, the analyst should never accept that a given weapon would produce a singularly distinctive pattern each time it is used. Minor variations in the weapon's contact or application may result in significantly different effects when recreating the stain.

In some instances, this difference may provide the analyst with a better understanding of "how" the weapon was used. If the weapon creates a distinctive pattern when used one way and another pattern when used some other way, this may become evident during recreation attempts. If present, such evidence factually defines the specific application of the weapon.

Dispersion characteristics also relate to our consideration of the presence of spatter on the subject. It is not an absolute that a subject involved in a spatter-producing event will have spatter on his person.[14] The lack of spatter may result from being behind the radiating pattern, where the level of dispersion is often quite small. Spatter ejects along any avenue of escape, but generally, this is away from the attacker based on the application of the weapon from that direction. Additionally, the manner in which the event takes place may limit the spatter dispersion in some manner, such as in the case of intervening clothing or bedding. Lack of spatter alone does not prove lack of presence or participation in the event.

We have to be cognizant that the interaction of a weapon with a blood source is a very dynamic event. Figure 9.13 demonstrates a spatter event associated with a shod foot striking a volume of blood. Several important considerations are evident by examining the photograph. First is that the blood ejected from this event is quite different. Note that on

Figure 9.13 A boot stomp demonstration. Note that the spatter produced is quite distinct. On the figure's right side, the spatter is the typical radiating pattern, while on the left it ejects in a more defined stream. Any number of variables in the initial conditions can affect the resulting pattern. (Photograph courtesy of Michael Taylor, Institute of Environmental Science and Research, Christchurch, New Zealand.)

Figure 9.14 The back of a T-shirt from a murder victim. Stain Pattern C is a spatter pattern radiating out from the shoulder. Stain Pattern B is spatter and possible cast-off stains on the mid-back. Both stain patterns furnish information based on the dispersion characteristics.

the right side of the photograph the blood ejected is "spatter-like"; the blood has broken up into small droplets and is widely dispersed. The blood ejecting on the left side of the photograph is much more like a streaming ejection, with large spine-like structures. The difference between the patterns produced on the left and the right side is a function of a myriad of possible variations. Blood volume, avenues of escape, and amount of pressure being applied all have some possible influence on the result.

Although boot stomps and similar events have not been studied in great depth, the figure does offer some general guidelines regarding spatter produced by a stomping. Note that the spatter is ejected out and away from the stomping foot. Thus, if spatter is produced we should expect the spatter to be on the non-involved shoe as well as any clothing covering the lower non-involved leg. We should not expect directional spatter on the stomping foot, unless both feet were involved. Another consideration is that if a shoe is involved in a stomping and produces spatter, the sole of that shoe by necessity will have been bloodied through contact.

Dispersion characteristics of a stain often provide the analyst with information regarding the general distance the spattered target was from the impact. They also verify that a given item was in proximity to the event in the first place. The pattern's configuration helps establish the relationship a given target had with regard to the impact. All of this, as Eckert and James explained, "… [helps] determine the relative position of the assailant and victim at the time the blows were delivered."[15]

Figure 9.14 depicts the T-shirt taken off a murder victim. There are several significant spatter patterns present on the back of this T-shirt, two of the primary patterns are labeled B and C. Figure 9.15 shows the spatter present on the right back shoulder (labeled C).

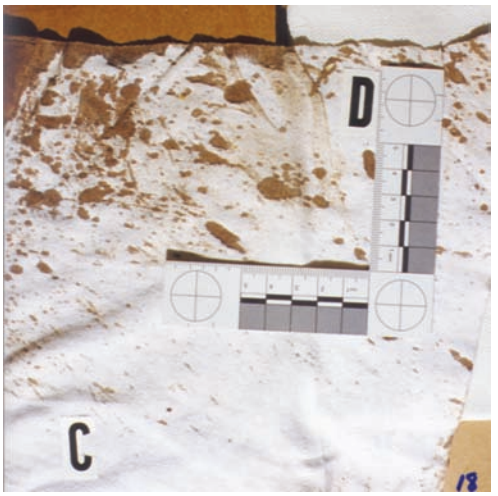

Figure 9.15 A closer view of the spatter associated with Pattern C in Figure 9.14. This pattern could be correlated to a number of scene patterns on surrounding objects based on the dispersion and the radiating effect, which effectively placed the victim in a general position when this event occurred.

Figure 9.16 A close-up photograph of Stain Pattern B from Figure 9.14. The small spatter intermixed in the larger stains was initially thought to be associated with a single event. DNA analysis established that the source of the smaller stains was the victim's wife, who was also beaten. Due to the small size of the stains and their orientation only on the mid-back of the T-shirt, this placed the T-shirt wearer in close proximity to his wife, with his back turned to her as the spatter-producing event occurred.

The pattern clearly shows a radiating effect to the right and the presence of a significant number of individual spatter stains. The further away from the origin, the more dispersed the pattern becomes. The pattern resulted from a blunt trauma beating with a bat-like object. Figure 9.16 shows a pattern labeled B. Evident in and around the larger stains in this pattern are numerous very small stains. The larger stains were first thought to be spatter

from a second victim, but DNA analysis verified these stains to be consistent with the victim wearing the T-shirt. Nevertheless, the lab chose to check the smaller stains overlaying the larger stains. These stains were determined to be consistent with the second victim's blood. They established that at the time of the second victim's beating, the T-shirt was in close proximity and oriented with the wearer's back to the event.

Spatter Resulting from Gunshots

Gunshot Spatter — Forward Spatter and Back Spatter

Impact spatter very often results from gunshot injuries. When a projectile strikes a target, sufficient force is transferred to the wound to create spatter in the form of a fine aerosol of blood droplets. As MacDonell illustrated, the droplets resulting from such an impact radiate out in a three-dimensional pattern that we refer to as a cone.[16]

This spatter not only follows a cone-shaped pattern in the general direction of the projectile, but may also create a back spatter effect. See Figure 9.17. Obviously, forward spatter patterns occur only when there is an exit wound of some nature, while back spatter is always possible. Figure 9.18 and Figure 9.19 graphically depict the development of the cone of forward and back spatter as a bullet passes through a bloody target. In addition to spatter, the force of the projectile may drive tissue and bone out of the wound. These bloody particles can create stains of their own.

With regard to the conical shape in both forward and back spatter patterns, the rules of dispersion hold true here as well. The closer to the target, the more spatter we are likely to find. In spatter patterns found very close to the target, the lack of dispersion combined with the size of the droplets involved (e.g., the atomized or mist-like stains) may produce a fine spray-paint effect (see Figure 9.20). In other words, the area contained within the pattern will appear as if someone used a spray can to create it. Further away, the pattern becomes more dispersed with fewer mist-like stains, eliminating this effect. Refer to Figure 9.10,

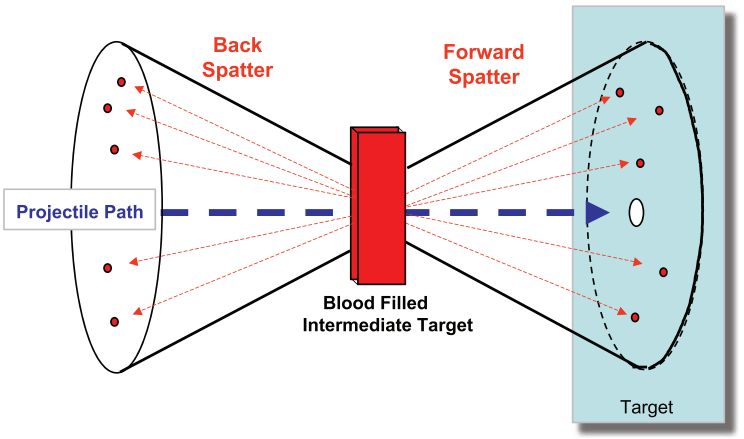

Figure 9.17 Spatter resulting from a perforating gunshot produces both forward and back spatter. The individual spatters project out from the source (e.g., the body) in a cone-shaped pattern, but generally do not travel very far because they are quite small.

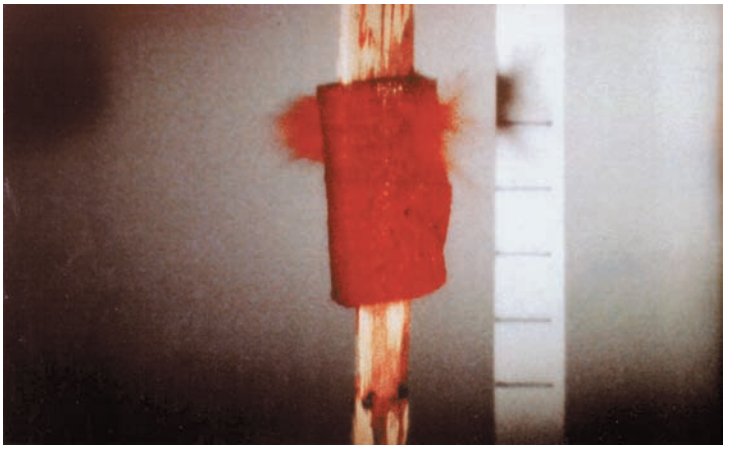

Figure 9.18 Forward and back spatter production. In this photograph, the development of the cone of spatter is evident. The bullet has passed through the sponge, moving right to left. Clouds of small droplets (both back and forward spatter) are ejected from the blood source.

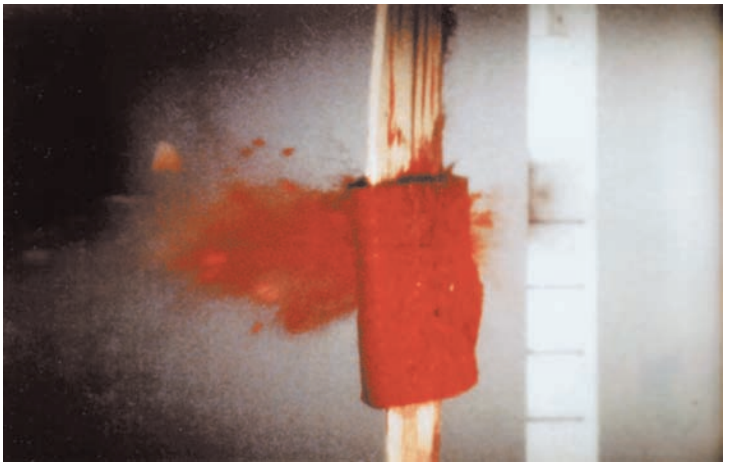

Figure 9.19 In this photo taken milliseconds later, the cone of forward spatter is well developed and extends out from the target. The cone of back spatter has peaked and is dispersing.

which shows this mist-like pattern. In Figure 9.11, the stains are more dispersed as a result of being further from the blood source.

Figure 9.21 shows four frames from a high-speed video of a bullet striking a blood-filled sponge. In Frame A, the bullet has struck the sponge and a red colored cloud is beginning to develop. In Frame B, the cloud is much more evident, yet in both Frames A and B the true nature of this cloud (e.g., the size of the involved droplets) is not evident. In Frames C and D, the cloud has expanded and become more dispersed and the tiny nature of the blood droplets making up the cloud is more evident. We can literally see the mist. The stains created from this mist are referred to as atomized or misting stains, sub-millimeter-sized stains. Such stains are created from such small volumes that, as discussed in Chapter 5, no matter what their angle of impact they will not demonstrate any ellipse and will appear generally circular.

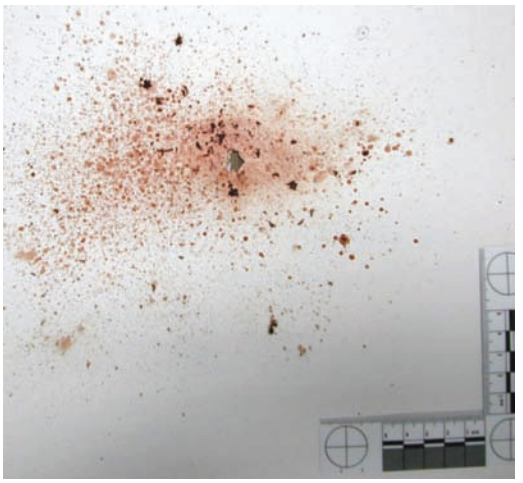

Figure 9.20 An example of a misting stain. Along with other sized spatter, gunshot events often create very small stains that are deposited close together. The result is a pattern that looks "spray painted" on. Based on the small mass of these sub-millimeter sized stains, they cannot travel far and are usually found on objects close to the event.

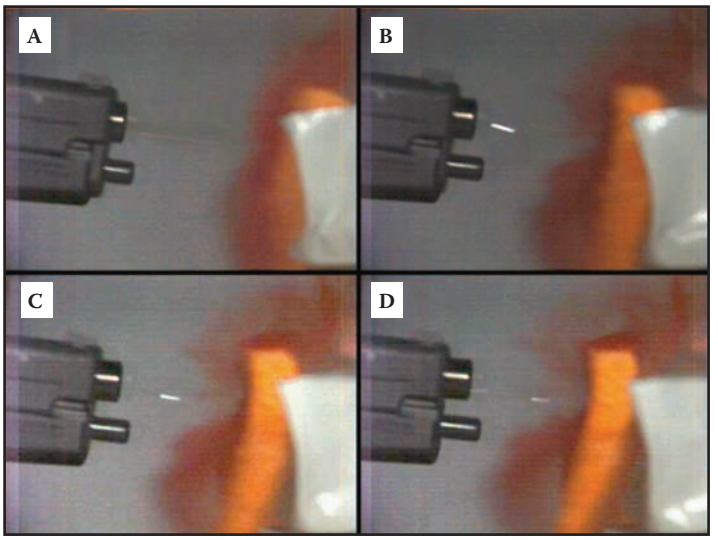

Figure 9.21 These four images were taken from a high-speed video of a bullet being fired into a bloody sponge. In Frame A, the bullet has already struck the sponge and a cloud of small droplets is developing off the surface. Through the four-frame sequence, the cloud ejects backward toward the weapon, becoming more dispersed with time. (Photographs produced in cooperation with Matt Noedel and the Midwest Forensic Resource Center, Ames, IA.)

Size Ranges of Gunshot Spatter

MacDonell and Bialousz, in their original work, clearly made the point that gunshot spatter included larger stains beyond the aerosol or atomized stains. They stated, "In addition to the fine particles, larger droplets, but essentially all under 1/8 in. diameter, will also be produced."[17]

Laber and Epstein placed the size of the mist stains as 0.2 mm or less, adding "Beyond this, the size of spatter produced by gunshot overlaps many other impact spatter patterns."[18]

Anyone conducting experiments will routinely find spatter from gunshots with 1 to 2 mm diameter stains intermixed among the mist-like stains. Once again, the presence of a wide range of spatter size in any pattern, including those created by gunshot, should not surprise the analyst.

Kinetic Energy, Wound Cavitation, and the Creation of Gunshot Spatter

From current references, it is apparent there is lack of agreement on what forces cause spatter during a gunshot injury. There seem to be many beliefs regarding the creation of gunshot spatter.[19,20]

Dr. Martin Fackler, through his efforts to understand missile-caused wounds, disputes portions of these beliefs, or at least some of the misconceptions that are often attributed to them. First, Dr. Fackler points to collapse of the temporary wound cavity as the probable source of most gunshot spatter, both forward or back.[21] Second, he established that kinetic energy potential does not define wound cavitation, nor is spatter produced by the sonic shock wave that precedes the projectile. In his experiments, Dr. Fackler discharged his weapons from 9 to 25 m from their targets. This eliminated "hot gasses" as the source of such wound cavitation.[22] This is not to say that in instances of close or contact wounds, hot gasses do not play a role in adding to tissue disruption. Yet, as Dr. Fackler points out, it does not cause an increase in wound cavitation itself.[23]

Dr. Fackler defines temporary wound cavity disruption by saying, "After passage of the projectile, the walls of the permanent [wound] cavity are temporarily stretched radically outward."[24] He likens the disruption process to that of a splash being made in mud. The potential for tissue disruption depends upon both the projectile mass and projectile velocity, while the utilization of this potential is based on construction, shape, and its interaction with tissue.[25] Dr. Fackler's findings dispute the widely-held belief that a higher-velocity projectile always produces a larger temporary wound cavity. Dr. Fackler also established that a bullet creates both the entrance and exit wounds milliseconds before the highest level of temporary cavity occurs.[26]

What we are left to consider, based on this information, is that the permanent wound cavity created by the physical crushing of tissue as the projectile passes through also causes a large temporary wound cavity. This temporary stretching of the surrounding tissues then collapses back to the permanent wound cavity. This collapse of the temporary wound cavity often occurs after both the entrance and exit of the projectile, leaving two holes from which blood may be ejected by the force of the collapse.

Double Shot Impact Events

An interesting effect related to gunshot spatter and this squeezing action occurs when two or more successive wounds are received with a short interval of time between the shots. During the intervening period, the first wound bleeds filling the wound track with blood and tissue. When the second shot impacts the body, the tissues surrounding the first wound compress as a function of the temporary wound cavity causing the blood-filled wound to "squirt" out its contents. The resulting spatter is much heavier than that normally associated with a single gunshot. The closer the two wounds are to each other and the longer the interval between the shots, the more dramatic the effect.

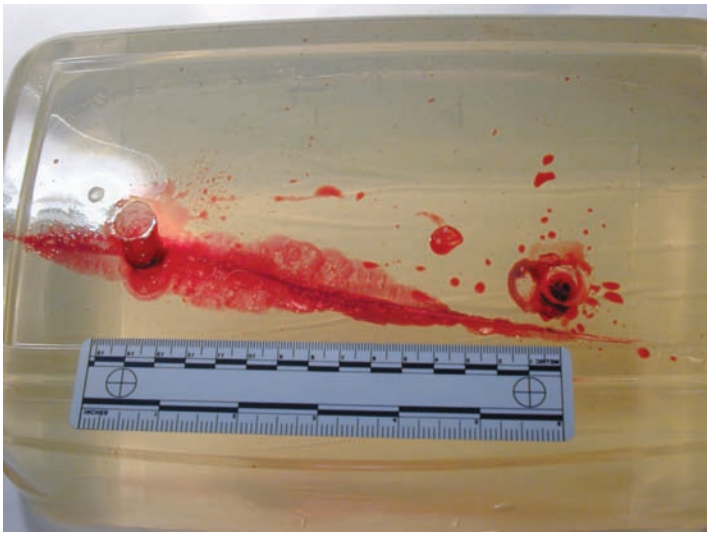

Figure 9.22 This photograph depicts a ballistic gel used to demonstrate a double shot impact. Two defects were produced and filled with blood. A bullet was shot through the defect on the left, while the path of the bullet simply passed close to the defect on the right. Figure 9.23 and Figure 9.24 show the resulting ejection of blood. (Photographs produced in cooperation with Matt Noedel and the Midwest Forensic Resource Center, Ames, IA.)

Figure 9.22 is a photograph of a ballistic gel block used to videotape this effect. Two small cavities were produced and filled with blood. The ballistic gel was then shot with a .22 caliber weapon from left to right. The alignment of the weapon was such that the bullet path crossed the cavity on the left, but only came in proximity to the cavity on the right. Figure 9.23 is a digital capture from the high-speed video taken of this shooting event. In this frame, the bullet has struck the ballistic gel, passed through the blood-filled cavity on the left, and passed to the right side of the second cavity. A very pronounced streaming ejection is evident emerging from the cavity on the left and a second ejection is forming from the cavity on the right. Figure 9.24 shows the same event milliseconds later. The mass of blood ejected from the left cavity is breaking up into spatter. The ejection from the right cavity is now as pronounced as the cavity that was struck by the bullet directly.

As one would expect, the blood-filled cavity through which the bullet passed ejects spatter. This ejection is in a volume greater than that associated with a single gunshot. It is a streaming ejection. The cavity where the bullet simply passed by and was compressed also ejects blood and spatter in a streaming fashion. What this simulation demonstrates is that compression of a wound track by a force such as a temporary wound cavity is sufficient to eject spatter in volume from a pre-existing wound.

Figure 9.25 demonstrates a case example of how much back spatter can be produced in these situations. The victim was shot once in the chest with a 30-06 rifle. He collapsed to a leaning position against the side of the vehicle, creating the contact staining. While he stood in that position, the wound track filled with blood. The victim was then shot a second time in the chest. The level of back spatter ejected from the two wounds is intense and atypical of the back spatter associated with a single shot (even that associated with a rifle). Spatters were found as far forward as the front door of the car.

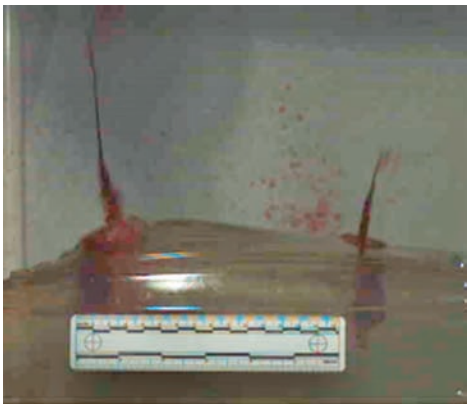

Figure 9.23 This photograph depicts the ejection from Figure 9.22. In this first image, a large streaming ejection is evident from the defect struck directly by the bullet. However, a streaming ejection is also developing from the defect on the right, where the bullet passed nearby. (Photographs produced in cooperation with Matt Noedel and the Midwest Forensic Resource Center, Ames, IA.)

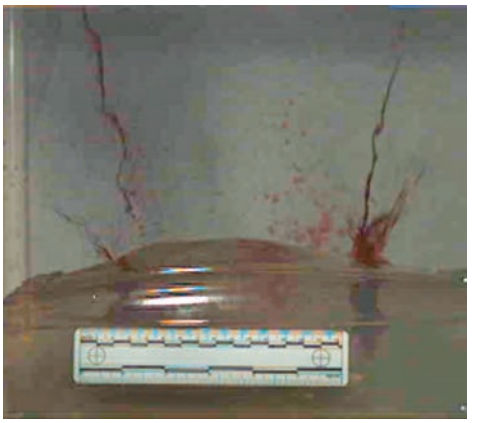

Figure 9.24 This second image shows the volume of blood ejected from the second defect. This sequence demonstrates that the temporary cavity produced by a bullet passing near a defect has the potential to eject significant volumes from a pre-existing defect. (Photographs produced in cooperation with Matt Noedel and the Midwest Forensic Resource Center, Ames, IA.)

Figure 9.25 A case example of the volume of spatter ejected as a function of a double shot impact. The victim in this instance was shot once in the chest, remained upright leaning against the car, and was then shot a second time. Spatter was ejected in volume as far forward as the front door. Double shot impact events produce spatter far in excess of a typical back spatter event.

Figure 9.26 depicts the wound associated with a second case example involving a double shot impact event. The victim was shot twice in the chest with a 9-mm handgun. The two wound tracks are within inches of each other. Based on the information provided by the shooter, at least 30 seconds passed between shots, which allowed blood to collect in the first wound. Figure 9.27 shows the volume of back spatter ejected to the wall and ceiling by this event.

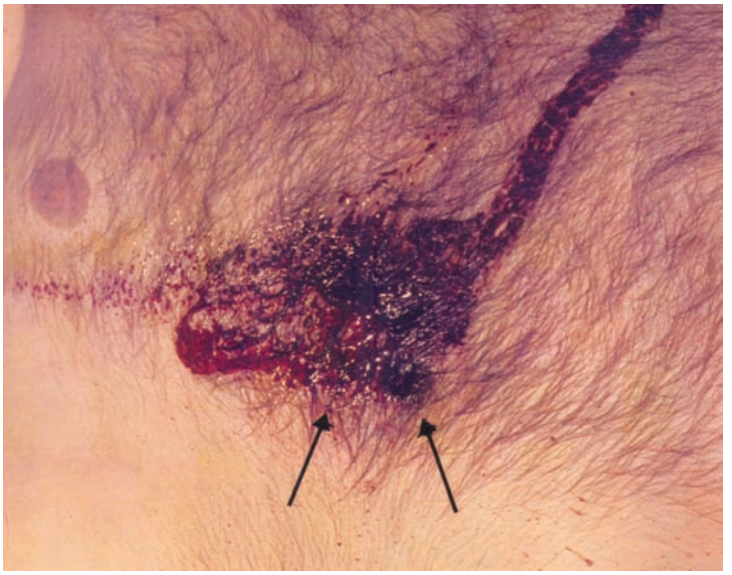

Figure 9.26 Another double shot impact event. The victim in this instance was shot twice in the chest with a 9 mm automatic pistol as he lay on his back in bed. Note that the two wounds to the chest are extremely close together (the arrows point to the wounds). The subject claimed a minute or less elapsed between the first and second shot.

Figure 9.27 A view of the ceiling above the victim of the two chest shots. The ceiling was 6 ft from the point where the victim lay facing it. The result of this double shot impact event is a pattern well in excess of the typical volume, size, and distribution found in back spatter events.

Gunshot Pattern Shapes and Dispersion

In considering typical gunshot spatter pattern shapes (unlike those associated with a double shot impact event), forward spatter patterns when present tend to be more symmetrical than back spatter patterns. This is probably due to the primary force of the impact being transmitted in the direction of the projectile. Back spatter patterns tend to be less defined.

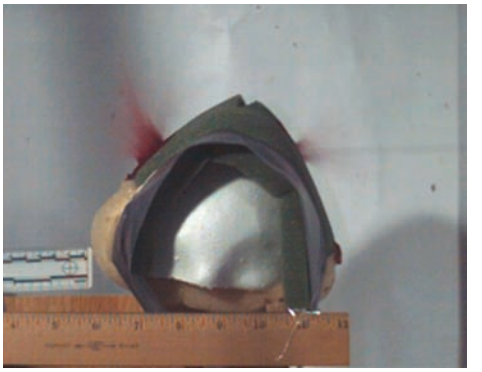

Figure 9.28 This image demonstrates that the cone of spatter produced by a gunshot event ejects generally perpendicular to the surface of the defect and not specifically in line with the bullet path. The bullet passed through the simulated head on a horizontal trajectory, left to right (a gray ghost image of the bullet is evident on the right side). The spatter, however, ejects perpendicular to the surface of the simulated head. (Photographs produced in cooperation with Matt Noedel and the Midwest Forensic Resource Center, Ames, IA.)

In considering where or in what direction the spatter is ejected, one might imagine that the ejection of the cone of spatter from the gunshot event would align to the path of the bullet. What actually occurs is the cone of spatter will eject generally perpendicular to the surface from which it is ejected. For example, Figure 9.28 shows a bullet striking a simulated head from left to right. In this high-speed photograph, the path of the bullet can be seen (the gray streak on the right side of the simulated head). This particular simulation placed emphasis on the left side of the target (the entry side had a large blood reservoir) and less so on the right side (the exit side); as a result, the back spatter cone is far greater than the forward spatter. This is simply a function of the simulation setup and is not typical of a normal single gunshot event. What this and other similar efforts define is that the cone of spatter is ejected generally perpendicular to a surface and does not specifically align with the bullet path. The back spatter event (left side of the simulated head) best demonstrates this, but the forward spatter cone (right side) also demonstrates this effect as well.

As with other spatter patterns, the presence of spatter resulting from a gunshot cannot be predicted. In some instances, the pattern may be heavy and obvious (see Figure 9.29). In other instances, the spatter may be extremely limited or nonexistent. Due to the dynamic nature of the event and the variations possible, there is no way to predict based on the wound alone where or how much spatter will be present. Characteristics of the wound (e.g., skin, tissue, bone) or positioning of clothing, hair, or other items can all impact on the presence of spatter or lack thereof. The size of spatter in these instances may also prevent the analyst from finding them to begin with. Dark surfaces, heavy weave, course soil, or vegetation can make it difficult if not impossible to locate these very small stains.

Of particular note to the analyst is that the presence of back spatter on the subject or weapon is in part dependent upon the manner and distance at which the weapon is held. Due to their small mass, these small droplets will carry only about 4 ft horizontally. Air resistance, if you will recall, is inversely proportional to droplet size. No matter how fast they are moving, the droplets rapidly lose speed and drop. There are also indications that in some instances these aerosol drops of blood dry almost instantly while suspended in

Figure 9.29 Heavy spatter resulting from several gunshot wounds to the head. The pattern in and around the door handle/arm rest was associated with the final perforating shot.

air. This too may be a factor in the lack of staining on surrounding objects. The small dried specks simply fall to the ground and fail to adhere to any surfaces.

It is also possible that while suspended in the air these droplets may move on air currents, which may result in deposits farther than 4 ft. This demands that an active air current of some kind is moving in the scene. In this instance, the droplets would "rain" down and be found only on the top of exposed horizontal surfaces.

Within the 4 ft range, a gunshot event may deposit small stains on the weapon, the shooter's body, or clothing. Figure 9.30 and Figure 9.31 depict back spatter on the inside surface of a crossbow, and Figure 9.32 shows back spatter on the hand of a suicide victim. The size of such stains, combined with their highly dispersed nature, can make them easily overlooked both by the shooter when cleaning up and by the investigator during subsequent contact. Back spatter is often deposited on the inside of the weapon's muzzle, external surfaces of the weapon, or on internal surfaces exposed during operation. See Figure 9.33 through Figure 9.35.

If the analyst wishes to establish that spatter was deposited into a gun barrel, or to determine how far it was deposited, one of the more functional means of doing this is a technique developed by Martin Eversdiijk. Using products like Forensic Sil,* Eversdijk developed a functional method of documenting not only the position of the spatter in the barrel, but a method that recovers the spatter stain as well. These products extrude the casting material using a trigger mechanism, which allows the material to be injected into any space. The product is automatically mixed in an extrusion tube, which eliminates concerns of improperly mixing the casting material. This allows the analyst to inject the casting

* Forensics Sil is a registered trademark of Armor Forensics.

Figure 9.30 An example of back spatter found on the inside facing of a crossbow. The owner was shot in the head while holding the bow in a firing position and pointing it at a police officer. The officer fired his weapon and struck the subject in the forehead. The presence of the back spatter supports the officer's contention that the victim was aiming the bow at the time he was shot. (Photograph courtesy of Lt. Johnny Kuhlman, Oklahoma City Police Department, Oklahoma City, OK.)

Figure 9.31 A second photograph of the crossbow, with a scale of reference. Several other small spatter stains are evident to the right side of the photograph. (Photograph courtesy of Lt. Johnny Kuhlman, Oklahoma City Police Department, Oklahoma City, OK.)

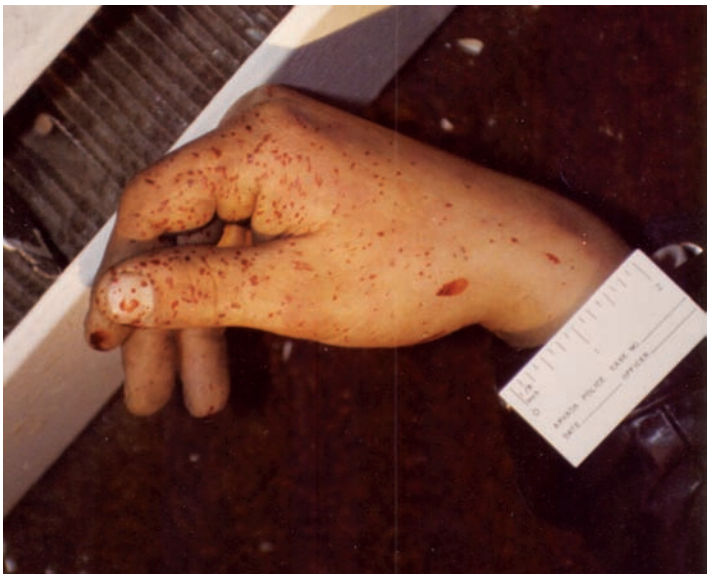

Figure 9.32 Back spatter present on the hand of a suicide victim. Also note the large elliptical stain at the base of the wrist. This is a good example of why targets capable of motion during an event represent a poor medium in terms of directionality. The large stain cannot be reconciled as being from the initial deposit of back spatter as it shows opposite directionality. This deposit must have occurred after the wrist rotated away from the body. (Photograph courtesy of John Graham, Arvada Police Department, Arvada, CO.)

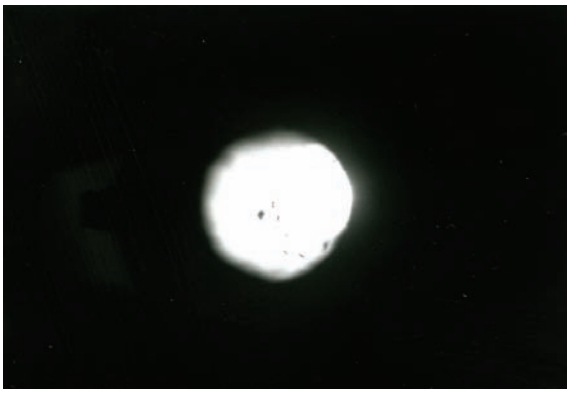

Figure 9.33 Blood deposited inside the barrel of a weapon. This photograph was taken using a fiber optic light inserted in the breech. (Photograph courtesy of Don Blake and Bill May, Norman Police Department, Norman, OK.)

material directly into the barrel of the weapon. To preclude any possibility of forcing blood further into a barrel, the material is injected from the breech end. Once the barrel is filled, a small tab of material is left in place at the breech end to assist in removing the cast. The normal cure time for such products is typically 3 to 5 min, but it is better to allow a longer cure in this circumstance. Once the material sets, if needed, the muzzle end of the cast is clipped flat allowing the entire cast to be pulled out the opposite side (see Figure 9.36). When the cast is removed, the casting material captures the actual spatter in the barrel and these spatters become an integral part of the outer surface of the cast. The spatter can

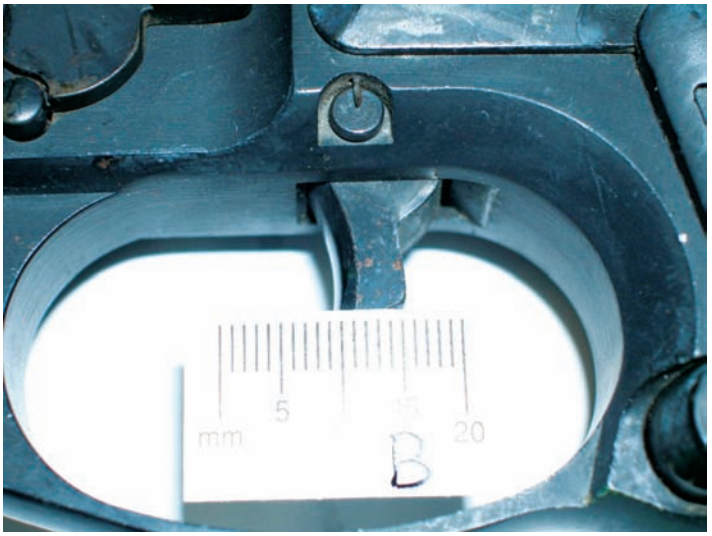

Figure 9.34 Spatter deposited on the trigger and frame of a semi-automatic. By contrasting the condition of the weapon, it is reasonable to predict that the hand that held the weapon was similarly stained.

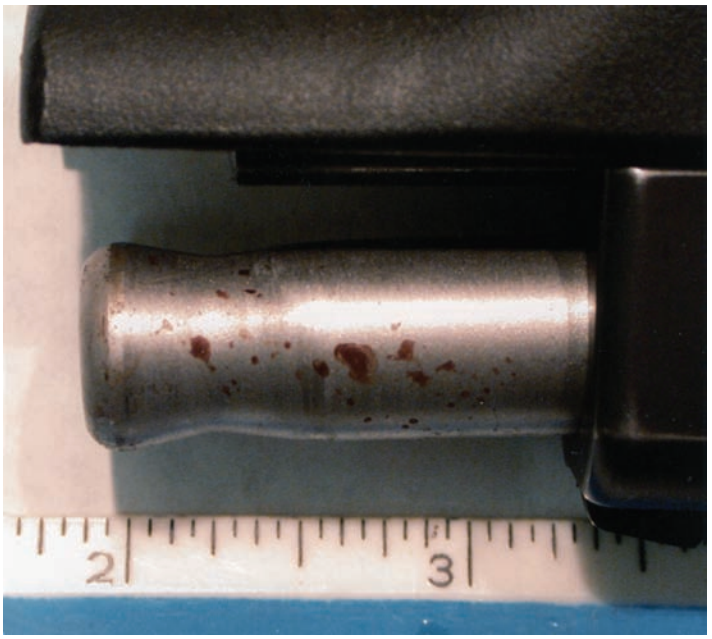

Figure 9.35 Spatter and hair deposited on the internal surfaces of a semi-automatic. As the weapon is fired, the slide moves back exposing the recoil spring guide of the weapon to the spatter event. If a suspect cleans the weapon after the event, these areas may be forgotten. (Photograph courtesy of Paulita McGuire, Indiana State Police, Indiana.)

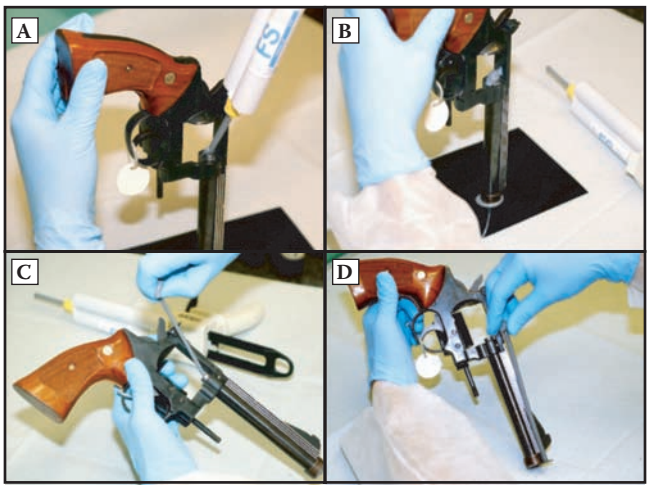

Figure 9.36 Using forensic casting material to document the depth of spatter in a barrel and to collect the spatter. In Frame A, the material is injected into the breech end. In Frame B, the material is allowed to cure and a small tab is left to assist in removing it. In Frame C, using the tab the cured material is recovered from the barrel. Frame D shows the complete cast. Figure 9.37 shows the result. (Photographs courtesy of Martin Eversdiijk, Amsterdam Police Laboratory, Amsterdam, the Netherlands.)

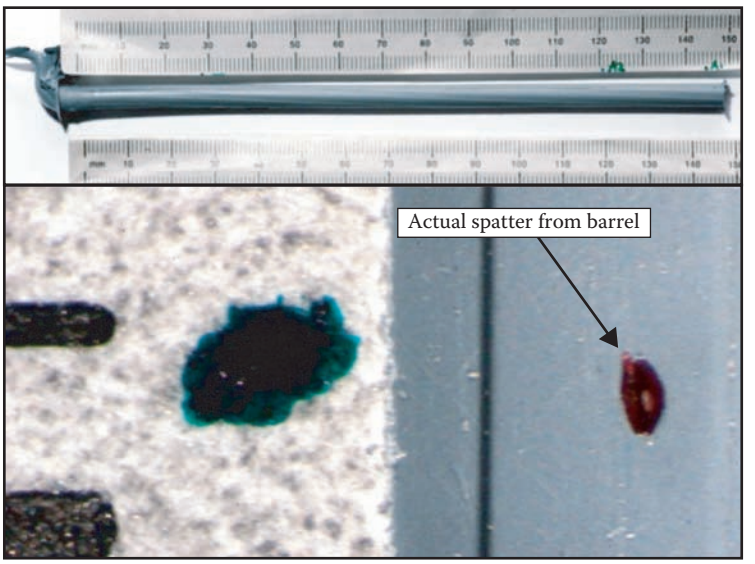

Figure 9.37 The top photograph shows the entire cast after recovery from the barrel. The lower photograph depicts a single spatter on the casting material. This is the actual stain caught in the cast. It can be evaluated like any other stain (e.g. DNA/serology). (Photographs courtesy of Martin Eversdiijk, Amsterdam Police Laboratory, Amsterdam, the Netherlands.)

be examined, measured from the muzzle end to determine how far into the barrel they were deposited, and, as they are on the surface of the cast, they can also be tested (e.g., DNA/serology) like any other bloodstain (see Figure 9.37).

Expectorate Blood

When a victim receives bleeding injuries to the mouth, nose, throat, or lungs and continues to breathe, spatter may result. The spatter resulting from the expiration of blood can range from heavy large stains to light mist-like stains comparable to those found in gunshot situations (see Figure 9.38). At times these stains can mislead the analyst and their similarities demand proper evaluation. For example, Figure 9.39 depicts expectorate blood on the sleeve of a husband who came to the aid of his wife after she was ambushed and shot multiple times by her ex-husband. A pattern of this nature could be mistaken for impact spatter.

Oftentimes, expectorate blood that mimics gunshot spatter is less vivid in its coloration. It may give an indication of being watered down and may exhibit a focused direction for the pattern. There may be evidence of air bubbles in the pattern, or traces of popped air bubbles (see Figure 9.40 and Figure 9.41). Additionally mucous strands (spine-like interconnections between individual spatter stains) may be present (see Figure 9.42). Keep in mind that the absence of these characteristics does not exclude expectorate as a mechanism. Expectorate blood is often recognized by correlating the position of the spatter with blood observed in the nose, mouth, or airway. If, however, no evidence of blood is found in the airway, either at the scene or during autopsy, expectorated blood is excluded as a possible source for the spatter. An additional test that can used to validate an expectorate event

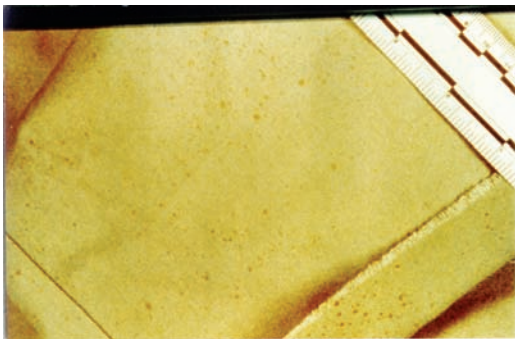

Figure 9.38 An example of expectorate blood. In this instance, the subject was wearing these cutoff jeans as he stood over a victim, whose throat was cut. Stains are evident on both the inside and outside of the pant leg. On fabric, the specific characteristics (e.g., vacuoles, mucous strands) may not be apparent and the pattern may appear as impact spatter. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, OR.)

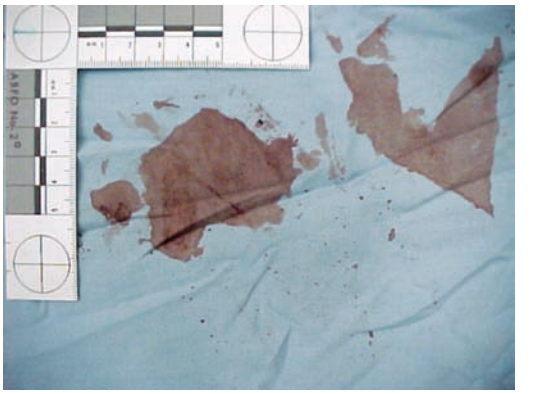

Figure 9.39 Expectorate blood on the sleeve of a man who came to the aid of a shooting victim. Initially of concern, the presence of similar spatter in the scene clearly from the expectorate event helped in understanding the true mechanism of creation of this pattern. Taken by itself, the pattern is certainly consistent with spatter associated with a gunshot.

Figure 9.40 After being stabbed multiple times in the back, head, neck, and chest, the victim began projecting spatter through his breathing (expectorate blood). The spatter landed on various articles to include this container. (Photograph courtesy of Sandra M. Roberts, Eugene Police Department, Eugene, OR.)

Figure 9.41 A close-up of the spatter from Figure 9.42. Note the presence of the bubble rings in the pattern. (Photograph courtesy of Sandra M. Roberts, Eugene Police Department, Eugene, OR.)

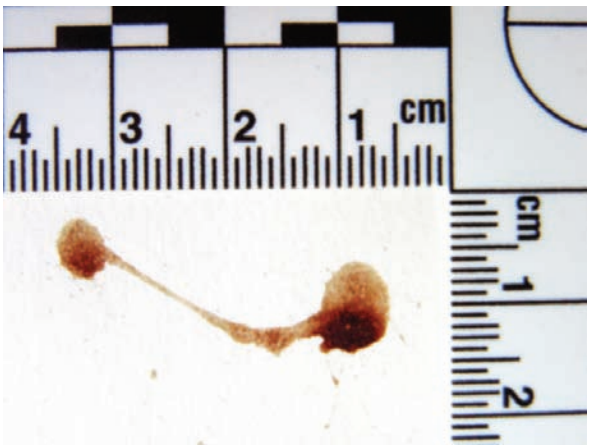

Figure 9.42 Mucous strands intermixed in spatter. This is another characteristic of expectorate stains.

is a chemical test for amylase. Amylase is a digestive enzyme that, although present in the blood, is present in saliva in significantly higher quantities. A serologist or qualified chemist should conduct such a test.

Fly Spots

Although not true spatter, another pattern that can be confused with impact spatter is the "fly speck" or "fly spot" pattern. Flies present at the scene will feed on blood found there. This blood is tracked about, regurgitated, and excreted by the flies. In the instance

Figure 9.43 An example of fly spots. Fly spots in some situations can easily mimic impact spatter. Often times it is only after considering position, time, and the entire scene that the source of fly spots will become evident.

of the tracking pattern, the marks are extremely small but a pattern may be evident on close examination.

In the case of regurgitation, the specks are remarkably symmetrical (see Figure 9.43). If the pattern is the result of excreted blood by the fly, subsequent movement can produce a stain with an elliptical component that may mimic directional spatter. Often, the analyst finds these patterns in warm areas where the flies rest, such as high in window corners or along walls where the sun strikes. Such stains will usually test positive for blood with a presumptive test. Obviously, care should be exercised in evaluating any abnormal patterns that meet these criteria. The source of the pattern as a fly artifact will usually be recognized by considering the pattern in concert with all of the other evidence.

Summary

We encounter impact spatter patterns frequently at crime scenes. The analyst's first issue is to properly describe and categorize them. Whatever method one chooses to use, its focus should be on describing those characteristics observed by the analyst. Differentiating spatter patterns based on the preponderant size of the stains is the most common method employed.

In considering patterns, the analyst must recognize that spatter size ranges widely from event to event and may range widely in a given event. Overlap in stain size is often encountered. This demands a cautionary approach by the analyst in evaluating any spatter pattern. Any decision to identify a pattern as "consistent with" or "inconsistent with" should be based on specific characteristics present in the stain.

A major point of concern when considering a spatter pattern is, as MacDonell put it, "a few bloodstains do not a pattern make."[27] Whichever stains are chosen for evaluation, the analyst should be confident that they have a relationship to one another.

The radiating effect of the spatter pattern certainly helps the analyst recognize this relationship, particularly in instances of blunt trauma. Considering the dispersion found

on an item can also help establish relationships with the scene. Spatter dispersion increases the farther away from the target the item is.

Unfortunately, the spatter pattern is impossible to predict in all instances. The presence of hair, clothing, bedding, and other items, or the characteristics of the weapon and how it was used, may affect the deposit of the spatter in the overall pattern.

In situations of gunshot, spatter may form as both forward spatter, which is projected outward in the direction of the bullet, and back spatter, which is projected back toward the weapon. This condition often results in deposits of spatter on the subject or other parties present near the assault. When attempting to distinguish forward from back spatter, the analyst may look for a less symmetrical pattern and fewer stains in the latter. Beyond that, little distinction is evident based on the stains themselves.

Back spatter patterns in gunshot situations may effectively place the individuals near the victim. The tiny misting stains associated with gunshot events rarely travel horizontally more than four feet from their source. When found on someone's clothing, it is difficult to refute that person's presence near the event.

Both expectorate blood and flies produce patterns that an analyst can misidentify as impact spatter. The analyst, if knowledgeable of such stains when considering the full context of the scene, is less likely to make such a mistake.

Keep in mind that bloodstain analysts do not "predict" the presence of impact spatter on clothing, the suspect, or even in specific areas in the scene based solely on the type of event. What they do is contrast the condition of the actual scene in terms of where and what level of spatter is present, and then using that condition, make valid predictions about what level of spatter would be present on anything in similar proximity. In doing so, they must still take into account issues such as the extent that the pattern radiates outward, the size of spatter present, and the dispersion level observed. Rarely, if ever, can absolute statements be made in the way of predicting the presence of back spatter. Statements such as "all gun shots to the head produce back spatter" or "a .22 head shot will not produce spatter" are not empirically valid statements.

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Understanding and Applying Characteristic Patterns of Blood

10

Throughout this book, we discussed many different types of patterns encountered in bloodstained scenes. This chapter attempts to explain how these patterns may assist in reconstructing the events in question.

Impact Patterns

Impact spatter patterns were discussed in detail in Chapter 9. Impact patterns are a significant form of bloodstain simply because they allow us to place an individual in a relatively specific position at a specific moment (the moment of a wounding). The ability to determine a point of convergence, area of origin, or simply directionality of the pattern allows the analyst to functionally corroborate or refute specific claims made by those involved in the incident. The power of this information cannot be overstated.

Case Example — Impact Spatter

A young woman was murdered along with her family in their home. She received blunt force injuries to her face, arms, and legs, as well as significant sharp force injuries. Of the blunt force injuries, only the facial wounds bled. The victim was found on her stomach a few feet inside her door. A spatter pattern was noted on a stub wall just inside and to the left of the bedroom door (see Figure 10.1). Additionally, further to the left inside the room, large spatters were found on the far wall and a chest of drawers. A broken tooth was found beneath the chest as well and identified as that of the young woman.

Using area of origin calculations, it became apparent that the victim was struck by the blunt force low and just inside her doorway (see Figure 10.2 and Figure 10.3). This was important in the overall reconstruction because there was also evidence that the sharp force weapon was employed directly in the doorway as well, indicating two modes of attack at the door and, in the context of this scene, suggested two active attackers.

Cast-Off Stains

Cast-off stains occur from two actions: centrifugal force as a bloody object is swung in an arc and cessation of the swing (see Figure 10.4 and Figure 10.5). Swing cast-off stains generally have a linear feature that make them easily recognized. This linear feature does not mean they all line up in a single line. The nature of the arc, the width of the item from which they were cast off, and the volume of blood available all play a part in the resulting pattern. Cessation cast-off patterns are more likely to appear as either impact spatter or a random arrangement of spatter because they are released at a more defined area (the point where the weapon or object stops its movement).

One way that cast-off patterns are important is that they may identify the minimum number of swings involved in the event. If the analyst believes the source of a cast-off is a

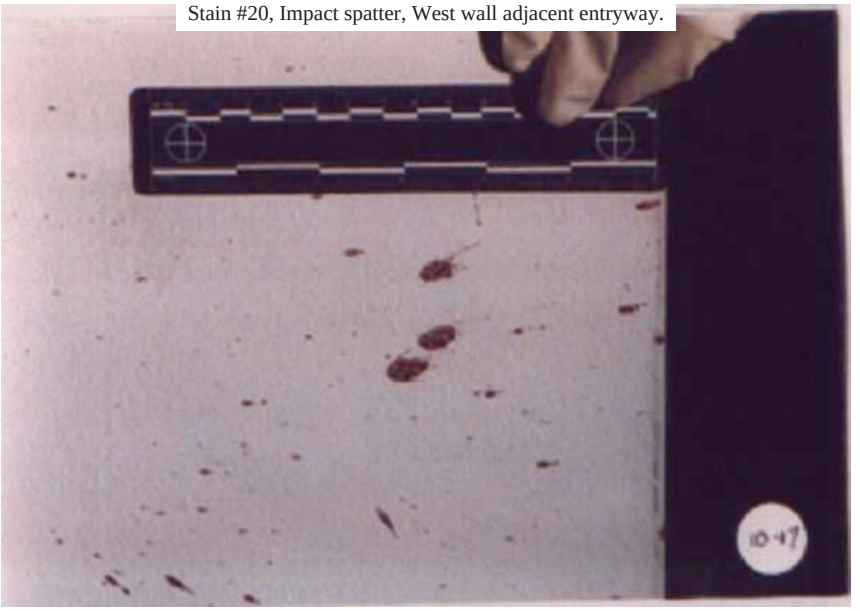

Figure 10.1 A spatter pattern found on a stub wall near the entryway to the victim's bedroom. Consideration of the pattern in terms of its directionality, point of convergence, and area of origin all assist in understanding the events associated with the murder.

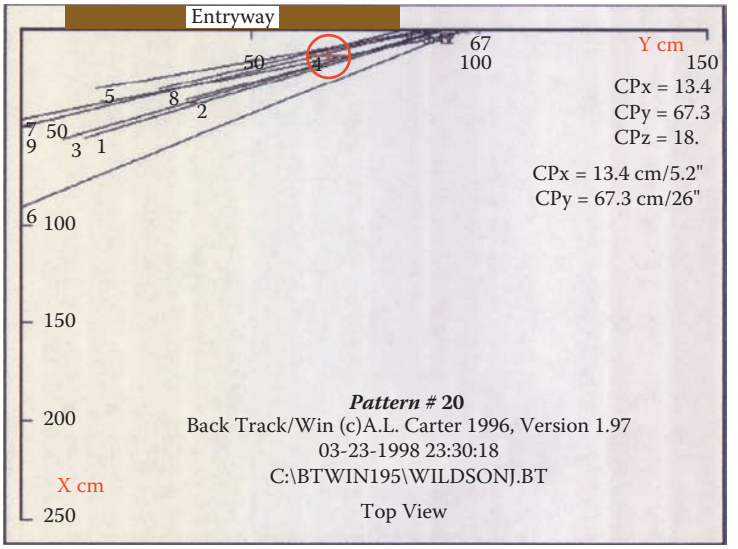

Figure 10.2 An annotated graphic from BackTrack/Win showing the top view convergence (the CPxy) for the pattern depicted in Figure 10.1. The circle shows the convergence and indicates it is just inside (5.2 in.) the doorway.

bloody weapon, by considering directionality of the stains in the pattern, the forward and backward swings become evident. As such, the analyst can group them, defining from this the number of swings. Quite often analysts take this number and add an additional blow, assuming that the first blow struck by the assailant will have produced insufficient blood to produce a cast-off.

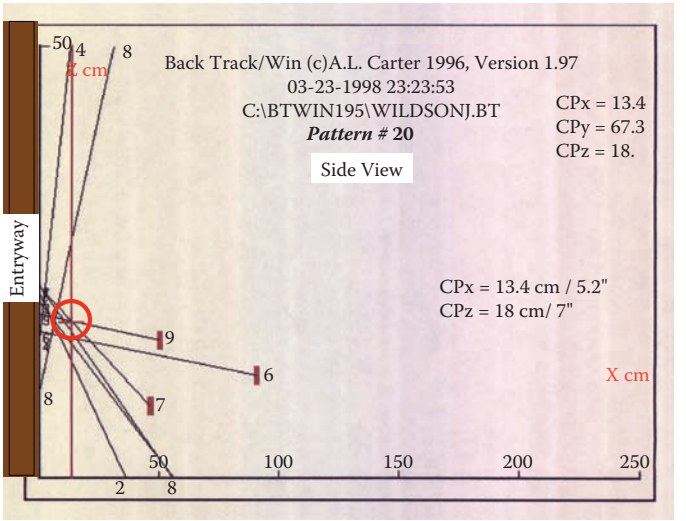

Figure 10.3 An annotated graphic from BackTrack/Win showing the side view convergence (the CPxz) for the pattern depicted in Figure 10.1. The circle shows the convergence from the side and indicates it is low (7 in. from the floor) and just inside the doorway.

Figure 10.4 An example of cast-off from a bloody object. The centrifugal force carries the blood away from the object, resulting in a pattern that helps identify the arc and direction of the swing. (Photograph courtesy of Metropolitan Police Forensic Science Laboratory, London, England.)

Figure 10.5 At the end of the swing, blood is also cast-off from the object as a result of the cessation of the swing and the inertia of the blood. (Photograph courtesy of the Metropolitan Police Forensic Science Laboratory, London, England.)

What this information cannot tell us is the total number of swings delivered during the event. That number can always be higher than the number of swings evident in the cast-off pattern. By identifying whichever is greater (forward or backward swings), the analyst is able to identify the minimum number of swings. This number may or may not correlate directly to the number of impacts received by the victim. The subject, however, cannot refute this minimum number. In some fashion, the subject's story must account for the information evident in the pattern.

The nature of the item from which the cast-off occurs has a distinct effect on the resulting stain. A broad or multi-surfaced object will result in a distinctly different cast-off pattern

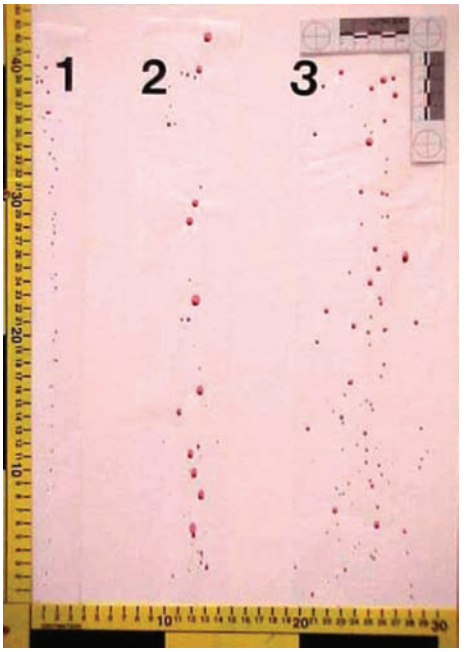

Figure 10.6 Cast-off patterns created by three different weapons, each swung one time. Pattern 1 has a very linear form with small-sized stains. Pattern 2 is linear, but the stains are dispersed across a broader area and the size of the stains is much larger than those in Pattern 1. Pattern 3 has a very broad swath in which the stains are dispersed and almost appears to be multiple events.

Figure 10.7 The three weapons that created the patterns in Figure 10.6. Knives tend to cause very linear patterns with small stains. Bats and clubs produce liner patterns, but their broad surface area results in larger stains in the pattern. The flat rough surface of the stick resulted in the release of stains across the entire surface area, creating the very broad pattern.

than an object with a single sharp edge or smooth surface. Figure 10.6 demonstrates the cast-off created by three different weapons. Pattern 1, the cast-off to the left, shows a distinctly linear characteristic, with small individual stains. Pattern 2, the middle pattern, has significantly larger individual stains. There is still a single line characteristic present, but it is less compact and the pattern is wider. Pattern 3, on the right, has a multiple line feature, enough so that on first examination one might believe that it was from multiple swings of the weapon. The stains are larger and the width of the pattern is distinctly wider. Figure 10.7 depicts the three corresponding weapons used to create the patterns. Sharp-edged weapons characteristically cause small stains with linear patterns. Bats and clubs will create larger stains and wider patterns as droplets are detaching from a larger surface area. The board and similar items often create very broad pattern characteristics.

Even when presented with a pattern similar to Pattern 3 in Figure 10.6, the analyst may be able to distinguish if the pattern is a single cast-off or multiple cast-off. If there are numerous discrete cast-off patterns in the scene, this should allow the analyst to recognize what a "single" pattern looks like. Obviously, if presented with only one or two of these wide type cast-off patterns, a measure of caution is necessary with regard to defining how many swings are indicated.

In addition to surface area, the volume of blood available during a cast-of event will affect the size and the number of stains. For any given weapon, the smaller the volume

available the smaller the stains will tend to be or there may be no cast-off action at all. If a significant volume is available, the stains will tend to be larger.

Cast-off patterns may give indications as to the nature of the swing; that is, left to right or right to left, and certainly the orientation of the swing in relation to the scene. Both play important roles in understanding the event. Note that an indication of right to left or left to right does not define the subject as either "right-handed" or left-handed" in and of itself. It simply suggests the orientation of the swing, which may allow the analyst to identify which hand created the swings. There are some distinctions evident between a cast-off created by a person's strong hand as compared to the weak hand. The strong hand cast-off is likely to be more fluid with a smooth arc. The weak hand, because it is not usually involved in such forceful blows, may show indications of a jerky nature which translates into a less smooth arc in the pattern. Normally, such observations are evident only under lab conditions and the analyst may never actually observe them in the field. This type of evidence and any decision made in this regard should be considered cautiously.

Case Example — Positioning by Cast-Off

Figure 10.8 depicts several small cast-off stains present on a far wall and windowsill in a bedroom. The entry to the room is to the left of the picture, while the far back corner of the bedroom is directly to the right. The orientation of the cast-off patterns is right to left and upward at about a 45° angle. The very small nature of the stains in the cast-off suggests a thin edged object; these stains are not consistent with hands, clubs, or any broad-surfaced object. An edged weapon and a club were utilized in the killing and the only viable source for the stains in the scene was the edged weapon.

In this instance, the stains belonged to a male victim and were found above a corresponding blood trail that started here and moved to the left. The victim's sharp force injuries were sustained to the left side of his face. The orientation of the cast-off patterns demand the object was swung very close to the wall. When considered in their totality, the only logical conclusion was that the victim was positioned facing the back wall of his bedroom, with the killer between the victim and the back wall when this attack occurred. This positioning of the victim and the killer at this particular moment was significant in understanding the overall event.

Figure 10.8 Cast-off patterns created by an edged weapon on a windowsill. Note the small size of the individual stains and the short length of the pattern itself. Knives have little surface area on which the blood can accumulate, usually resulting in much smaller stain patterns.

Figure 10.9 A student involved in a cast-off experiment. Note the presence of droplets on his back. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

We may also consider cast-off trails and their respective change on the surfaces involved. Remember, the source of the blood in our cast-off pattern is invariably that of the victim. The analyst may see the start of the first cast-off high on the wall, with the second one lower, and a third almost at the base. Correlating these stains with other patterns such as impact patterns, wipes, and swipes would aid the analyst in recognizing the change in the victim's position as the subject delivered the blows. When considering cast-off patterns, remember that not all cast-offs are from offensive actions (e.g., swings of bloody weapons). The victim or attacker can also produce such patterns while swinging bloody appendages. The analyst should consider the condition of the victim's hands, hair, or any other objects in the scene when attempting to identify a viable source for the cast-off pattern.

In situations involving exaggerated swings, it is not uncommon to discover small cast-off stains on the back surfaces of the attacker's body and clothing. The cessation action at the terminus of the back swing may cast small droplets onto the shoulders, back, and legs. See Figure 10.9 and Figure 10.10.

Case Example — Cessation Cast-Off

A woman claimed to have been asleep on her sofa when an intruder with a butcher knife attacked her two young sons. She was quite specific that she was on her back on the sofa nearby as this attack occurred and was awakened when the intruder began attacking her. Both boys suffered significant sharp force injuries from a butcher knife. There were many inconsistencies in the woman's statement when compared to the scene, which led to consideration of her as a suspect.

When looking at the nightshirt worn by the woman, there were many patterns of interest on the front, but of particular note was a small spatter on the back (see Figure 10.11). When

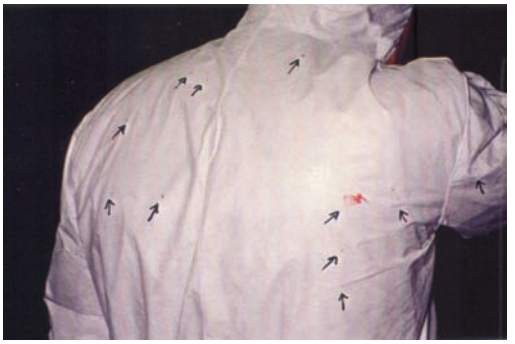

Figure 10.10 A close-up view of the student's back after the experiment in Figure 10.9. Each arrow points to spatter (the arrows do not identify directionality) and other stains. In this instance, the spatter may be the result of both cessation action during the back swing and droplets thrown from the weapon in high overhead parabolic arcs. These types of stains are often found on the perpetrator's clothing. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

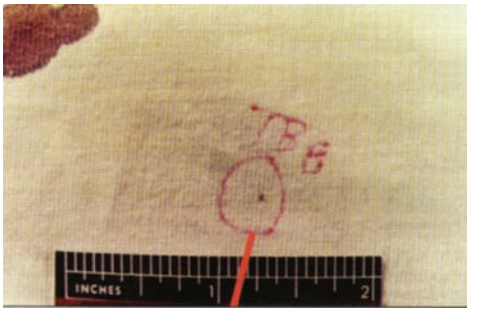

Figure 10.11 This single spatter stain was found on the back shoulder of a murder suspect. The blood belongs to one of two victims in the house. Based on her story, this area was not exposed when that victim was attacked, so it cannot be reconciled in that context. It is, however, consistent with the cessation cast-off observed on those who have been involved in swinging bloody objects. There were two additional cast-off stains of the same victim's blood noted on the front shoulder.

evaluated, the blood in the spatter was identified as belonging to her son. Her physical position as she claimed was not supported by the presence of the spatter. It should not have been present, as this area was not exposed during the attack of her son. The intruder's subsequent attack of her was directed from the front and did little to explain the presence of these stains. The stain was, however, consistent with cessation cast-off based on size and its position.

Projected Blood — Spurt and Gush Patterns

Several things characterize blood that has been projected under pressure in a stream or in volume: spines, serpentine patterns, and volume. The most typical occurring projected patterns are the gush or spurt patterns. The spines found in these patterns reflect both the force behind the projection and the volume of blood projected. Figure 10.12 shows an arterial projection following a beheading and illustrates just how distinct these ejections can be. As MacDonell illustrated, such patterns as a whole may look quite different, depending upon the location of the artery breached.[1] Often these patterns will show the pressure fluctuations of the circulatory system, with peaks and valleys that produce the serpentine pattern. Figure 10.13 is an excellent example of this and shows an arterial spurt pattern resulting from a severed carotid artery. Both spurt and gush patterns demonstrate a volume characteristic. In spurts, volume will be evident in the form of small flows from individual stains, large elliptical stains, or in the overall volume deposited in the scene. Figure 10.14 is another arterial spurt. Note the large volume elliptical stains on the doorway. Gushes always involve large volume accumulations. The primary stain often appears as a pool, but with the additional associated characteristics (e.g., spines and spatter) emanating from it.

Figure 10.12 Arterial ejections resulting from an execution (beheading). Based on weapons and clothing, this execution occurred in South East Asia somewhere in the period of 1900–1930. Note there are three major streams ejecting. These are very likely the right and left carotid arteries and vertebral artery. (Photograph courtesy of Malcolm Fletcher, United Kingdom.)

Figure 10.13 The patterns present on the drywall resulted from a severed carotid artery. Note their appearance as if squirted onto the wall with a small hose or hypodermic. When directed straight toward the target, arterial spurts often demonstrate this characteristic. (Photograph courtesy of T. Daniel Gilliam, Larimer County Sheriff's Department, Fort Collins, CO.)

Figure 10.14 Another arterial pattern. In this instance, many of the stains are large and elliptical. An arterial spurt that strikes a target at a glancing angle, rather than directly on, will often demonstrate these types of characteristics. (Photograph courtesy of SA (Ret) Steve Chancellor, USACIDC.)

If an arterial ejection is directed upward and subsequently falls back to a target as a function of gravity, the resulting pattern may mimic a drip. The pattern will usually consist of a number of randomly-oriented large spatters. This particular type of pattern is often referred to as arterial rain. In the same fashion, because of size and having fallen out of their parabola, arterial ejections onto horizontal surfaces that lead into arterial patterns on vertical surfaces are often misidentified as drip trails. The reader may wish to refer back to Figure 3.9 in Chapter 3 to understand this effect.

An important correlation from arterial spurts and gushes is the condition of the victim and his movement through the scene. Given a breached artery and a live victim, some evidence of the projected blood will be found. Just the same, the movement of the victim or lack thereof will be evident based upon arterial patterns. Lacking such stains, one would surely question whether the victim had any level of blood pressure at the time the artery was breached. It is possible that clothing or other items over the wound will baffle or block the stream, preventing an "ejection." Stopping the ejection does not stop the blood loss; if the victim is alive, there will usually be a significant volume of blood present.

Case Example — Arterial Gush

Figure 10.15 and Figure 10.16 depict the arterial gush pattern produced by a shotgun wound to the chest. In this instance, after being shot in the heart by the weapon, the man walked a total of 27 ft down the sidewalk and over the lawn before collapsing. Throughout his movement, he was ejecting significant volumes of blood forward from the heart wound.

Expectorate Patterns

Expectorate patterns are also helpful in understanding the condition and the movement of the victim in the scene. If blood is introduced into the victim's airway or respiratory system through some wound or mechanism, breathing on the part of the victim will eject the blood out in the form of spatter. The characteristics most common to expectorate spatter are small vacuoles or burst air bubbles, dilution of the stain from saliva, and/or mucous strands intermixed in the pattern. Such patterns are important because they tell us that the victim was still breathing when the patterns were produced, and they help us understand the general orientation of the victim when they were produced.

Case Example — Expectorate Spatter

After a minor altercation at a bar, a man was followed and beaten on the street nearby. When found he was supine on the sidewalk and died as a result of internal brain hemorrhage. Around his head were various items of paper that appeared to have been taken from his wallet. The front aspects of his clothing and these items all had small spatter on them. The spatter on the paper items showed evident air vacuoles (see Figure 10.17).

Based on the presence of similar staining in a halo effect around his head and the lack of such staining beneath him, it was evident that after receiving some number of blows (in which his nose began to bleed) the victim was, for the most part, in a position consistent with his final position. There was no evidence to support any significant movement (e.g., defensive or offensive behavior) by him.

Figure 10.15 An arterial gush. The pattern on the sidewalk resulted from a wound to the heart. As with most gush patterns, both volume and spines are evident throughout the pattern.

Figure 10.16 Another photograph of the gush pattern in Figure 10.15. In this instance, the victim was shot in the heart with a shotgun. The pattern demonstrates he remained mobile and clearly indicates his path.

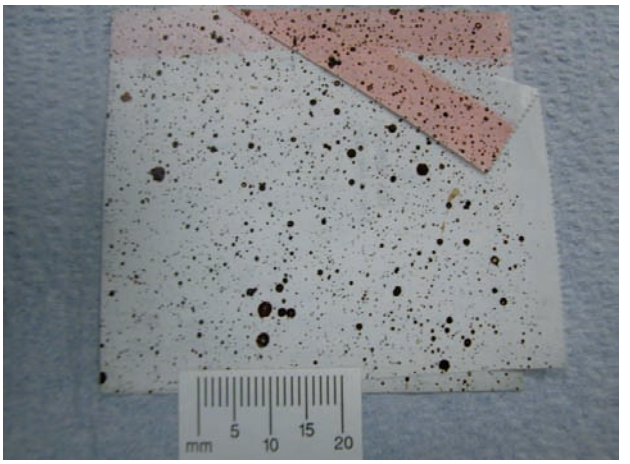

Figure 10.17 Expectorate stains deposited on an item of paper found near the victim's head. The small vacuoles found in the various individual stains are the major indicator of an expectorate event.

Drips and Drip Trails

Drips and drip trails can be utilized in any number of ways in reconstructing a scene. First, they provide information relative to where injured parties or bloody objects have been or were moving between. This knowledge, combined with directionality of the drip, can aid in sequencing different activities.

Another consideration and one that is often ignored is that a simple drip or drip trail can tell the analyst who was injured. Drips and drip trails are encountered throughout the scene, but one can never assume they are all associated with the victim. Particularly in stabbings, where self-wounding of the attacker is common, these trails may suggest that individuals other than the victim were injured as well. Drip trails that do not correspond to movement of the victim (e.g., drip trails that extend out and away from other obvious stained areas) should always be sampled and tested. Granted, a non-replenishing blood source (e.g., a bloodied knife) can drip for a rather extended distance, perhaps as much as 100 ft in some instances, but this is not common and requires a significant amount of blood on a large surface area. Extended drip trails, and even limited drip stains leading away from the action, may indicate other involved parties.

Case Example — Drip Trail

Five women were found stabbed in a small room in a house in Oklahoma. The bedroom scene was, to say the least, quite bloody, but the remaining scene was generally clean, with the exception of several drip stains found at the front door and porch. Given the volume of blood present, these stains could have easily been considered nothing more than drips of the victims' blood from the killer or his weapon. Nevertheless, they were sampled. In fact, the stains were not associated with any of the victims. The case occurred prior to the existence of a DNA database, but investigators sent the DNA profile to other organizations and asked that they watch for any similar profile. Years after the murder, a DNA analyst in California made a cold hit matching the DNA from the Oklahoma scene. The palm prints of the individual associated with the DNA were checked against bloody palm prints from the crime scene and they too matched.

Pattern Transfers

Pattern transfers are probably the most overlooked evidence within any given scene. Blood is extremely adhesive in nature. Once a small amount contaminates some object, that object will then contaminate others. A little blood goes a long way and results in pattern transfers throughout the scene.

Any comparison of a pattern transfer to the item we believe created it is likely to be limited to a finding of "consistent with" or "inconsistent with" based on class characteristics. Granted, the analyst would prefer to make "identifications" based upon individual characteristics, but that does not happen in very many cases. Nevertheless, when dealing with a detailed pattern transfer, analysts should be given an opportunity to consider such evidence in the hopes of making an identification.

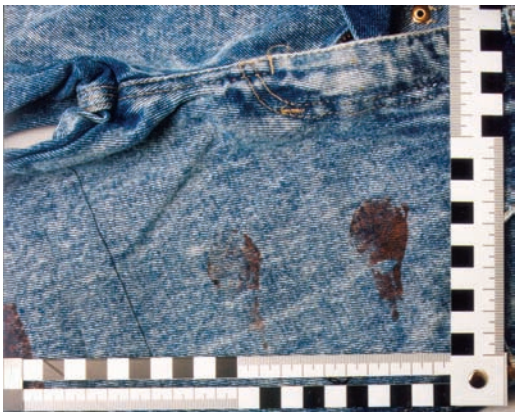

Figure 10.18 A pattern transfer on a fabric, in which the general characteristics of the object are evident. Note the elliptical voided area in the lower third of the pattern on the right. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

Figure 10.19 The tool that created the pattern in Figure 10.18. Note the beveled edge where the tool head and shaft come together. This characteristic is clearly visible in the pattern in Figure 10.18 as the elliptical area void of blood. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

Consider Figure 10.18. Present on the pant leg is a pattern transfer that has a small unstained section in the pattern. This unstained section exhibits a distinctly curved edge. Figure 10.19 is the object that created the pattern. At the point where the tool head and shaft join, the reader will note a beveled edge, the outline of which corresponds to the curved feature evident in the unstained area. Through simple re-creations, the analyst can easily correlate the class characteristics of the tool to those present in the stain. It is also possible that a tool mark examiner will match individual characteristics caused by accidental marks or flaws on the tool.

Even lacking such individual characteristics, the class characteristics in the pattern are strong evidence. They often point the analyst to objects within the scene. The nature of these patterns is unlimited, and the correlation of any given pattern transfer to an object may or may not be as simple or as evident as the previous example.

In deciding if an object is consistent with a pattern, experimentation by the analyst is necessary. Such experimentation occurs only after all other forensic examinations are complete. If only comparing class characteristics of the item, the analyst may use an item of similar construction. However, do not expect to make a Xerox copy of a scene pattern in every circumstance. The dynamics of how much blood was involved, how the object came in contact with the surface, and the surface characteristics all affect the resulting stain. The analyst is rarely presented with situations that allow reproduction of the original event in absolute detail.

There are two basic approaches to evaluating pattern transfers. The first considers looking for a unique landmark within the questioned stain and comparing that to the standard, while the second starts with characteristics in the standard and looks for similar ones in the questioned stain.

Don Coffey offers this approach to the first method:

- Seek a landmark in the questioned stain — some pattern or defect that is distinct.
- Compare this characteristic against the class characteristics found in the standard. Expect a class match at best, but always seek an individualized match.
- Because of the complexity or dynamic manner in which the questioned stain may have been created, do not expect an exact match. Creation of the standards must also be a dynamic process.
- Consider the use of "screen positives" to compare a questioned stain with a standard.
- The more eyes viewing the stain the better, as this eliminates tunnel vision on the part of the analyst.[2]

The second method of comparing pattern transfers begins with the standard. Our initial evaluation of the scene pattern may direct us toward some object or group of objects. Using these, we create standards and look for specific class characteristics. We then compare these characteristics with the questioned pattern.

It might seem that the two methods are distinguished by mere semantics, but in fact, both change the perspective the analyst uses in viewing the stain. The utilization of both methods may be of value.

In considering pattern transfers and the dynamic nature of their creation, the manner in which the target surface and item come together can make a drastic difference in recognizing the resulting stain. Recreations in which we simply change the item's orientation to the target often result in radically different patterns.

For instance, consider the butterfly pattern caused when a bloody knife is wiped with a fabric (see Figure 10.20). If the cloth is folded over and the knife wiped close to the fold, the classic pattern will occur. If the cloth is folded and the knife wiped further away from

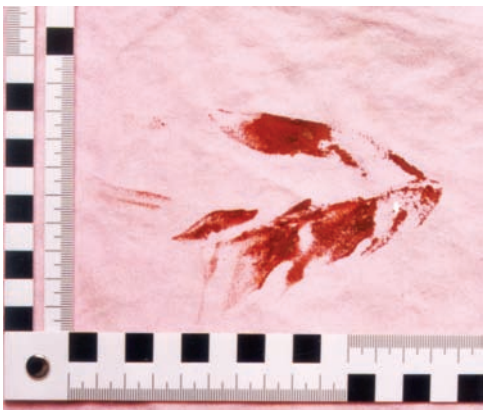

Figure 10.20 A butterfly pattern transfer created by the wiping of an edged weapon on cloth. Characteristics evident in the pattern include the back strap of the blade and the general blade dimensions. The back strap width (the thickness of the blade) is often the most evident characteristic in a butterfly pattern. These dual linear marks may appear when nothing else is evident from the blade. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

Figure 10.21 The knife that caused the pattern in Figure 10.20. Although there are no evident individual characteristics present in the pattern, we can still compare general dimensions (e.g., blade width and back strap width) against the pattern. Such an examination is likely to produce a "consistent with" or "inconsistent with" finding. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

the fold, the analyst ends up with each half of the butterfly in two widely separated locations on the cloth. Whenever the analyst produces standards for comparison, a major consideration is the orientation of the tool or object to the target. Never assume that the way you put two items together is the only way to put them together. Minor differences in this orientation can result in drastically different patterns.

This butterfly pattern, associated with edged weapons, often provides very distinct information regarding the features of the weapon creating it. The example in Figure 10.20 shows a slightly separated butterfly pattern. The pattern has a clear representation of one side of the blade. The edge of the back strap of the blade and the blade itself are quite distinct. Measured at a point approximately 30 cm from the apparent tip, the width of the pattern is 17 mm. Figure 10.21 is the weapon that created the pattern. A measurement of the blade at this or another point allows comparison to the pattern.

Knives are not the only item capable of creating a distinct pattern; nearly any object has the potential to produce pattern transfers of some nature. The more distinctive the object, the more likely it is that the analyst may recognize the source of the pattern. One particularly distinctive pattern transfer is the hair swipe. These patterns often show characteristic bifurcated endings (see Figure 10.22). Commonly encountered pattern transfers include fingerprints, handprints, and foot or footwear prints. All of these patterns can help the analyst detail motion in the scene. Combining the information present in the pattern with the concept of a repetitive pattern transfer, the analyst can often detail actions by the involved parties.

Case Example — Pattern Transfers

A woman was shot with a shotgun in a front bathroom of her home. Her husband reported a rather convoluted scenario of self-inflicted wounding in which he was a party, but specifically claimed he put the shotgun down in the same bathroom after the event and never moved it again. The barrel of the weapon was lightly smeared with blood when found. In a back bedroom of the house, there were additional indications of an altercation (e.g., small impact spatter on the

Figure 10.22 A classic hair swipe pattern transfer. Note the many small bifurcations (small v's) evident in the pattern. These are very specific and define the object that caused the pattern as being hair or a hair-like substance. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

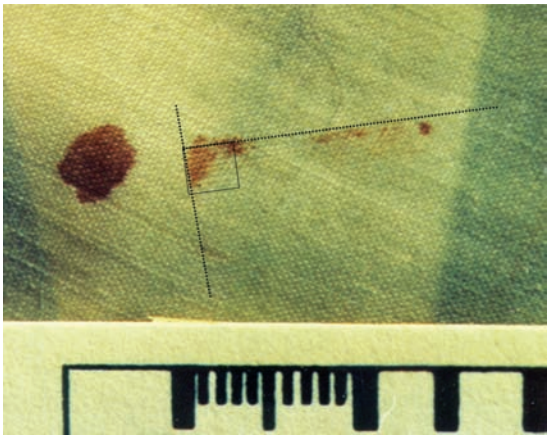

Figure 10.23 Oftentimes a pattern transfer is anything but specific and therefore not considered of value. In this instance, we have a simple stain that suggests the corner of some item. On close examination, it became evident that the two edges of the stain were not at right angles to each other, but rather formed an 88° angle. The barrel of a bloodied weapon used during this event had a distinct cut, which formed an 88° angle and shared other basic size features with the stain. During recreation attempts, the examiner was able to recreate the pattern using the cut barrel.

bed and surrounding objects, a drip trail leading to the front of the home that had been cleaned up, and a broken master-bathroom door). Of particular note was a pillow on the bed with an odd pattern transfer. This pattern transfer in the woman's blood showed two linear features that were almost at a 90° angle to one another. When measured, however, the angle was actually 88° (see Figure 10.23). Given the different ways in which an object with straight edges might have been in contact with the pillow, this angle, in and of itself, was not significant.

The shotgun used in the situation had been shortened by the owner, who manually cut the barrel with a hacksaw. When examined, the barrel was cut at an angle consistent with the angle in the pattern. During recreation attempts, this weapon was bloodied and tossed onto a similar surface (a pillow), resulting in a pattern nearly identical to that found at the scene.

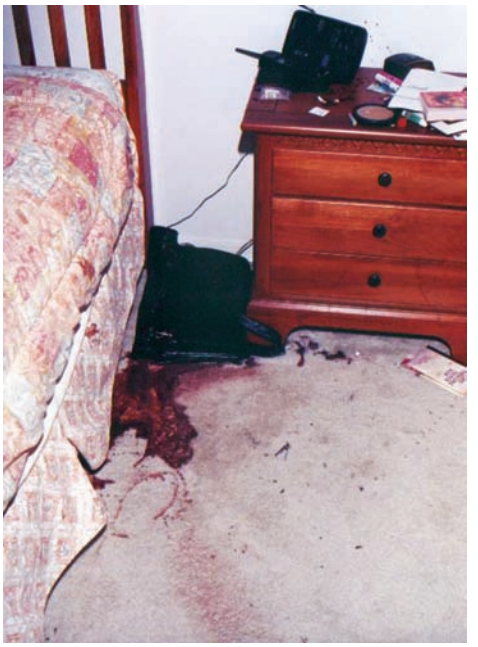

Figure 10.24 A shoe pattern transfer on carpet at a death scene. This photograph was taken after removal of the victim. Compare this to Figure 10.25.

> Although it might be argued that other items can create such a pattern, utilizing Haig's "Limited Universe" principle, there were no other bloodied objects in this scene. The weapon was the only bloodied item present that had a capability to produce the pattern on the pillow. Yet the husband claimed that there was no altercation in the back bedroom, the pillow was never in the front bathroom, and he had never moved the shotgun from the front bathroom after the wounding. The physical evidence simply did not support the husband's claims.

The use of "screen positives" as mentioned by Coffey is a functional method of comparison for many pattern transfers. This method is based on the work of Peter McDonald, found in his book *Tire Imprint Evidence.* McDonald stresses that "screen positives are the most effective way of making visual comparisons."[3] The method involves making clear transparencies of the standard and questioned stain and then evaluating them with the use of a light box. This method is best suited for circumstances in which the pattern transfer is on a rigid substrate. Coffey cautions the analyst in its use, however, because point-to-point comparison is not always possible.[4]

One major caution is in order when considering pattern transfers. If possible, evaluate them on-scene or through photographs exposed early in the scene processing. Post-incident pattern transfers occur as a matter of routine. Police, medical, coroner, fire personnel, and even animals can create post-incident pattern transfers. If an object is still wet and then moved, it is likely to cause a transfer. Additionally, these same personnel are themselves moving in the scene and may end up tracking blood. Figure 10.24 depicts a shoe pattern on the carpet adjacent to the bed. Figure 10.25 depicts the scene prior to disturbance by EMS. The shoe mark is noticeably absent and is obviously a post-incident artifact. Figure 10.26 depicts another post-incident pattern transfer created by movement of a pet in the scene.

Figure 10.25 The same area as shown in Figure 10.24 prior to removal of the victim. Noticeably absent is the shoe mark by the bed. Post-incident pattern transfers will occur and the analyst must be cautious to recognize them.

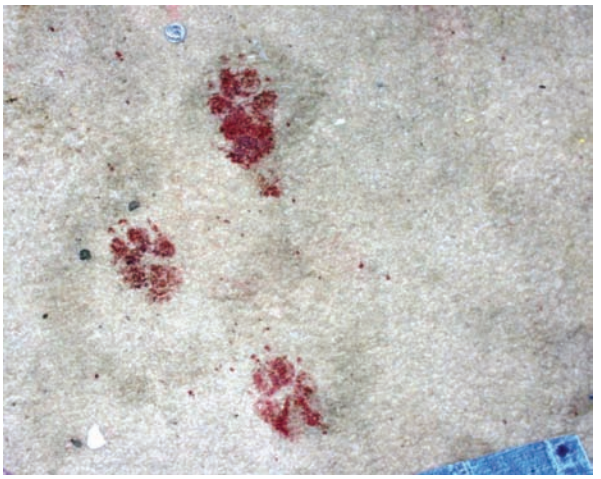

Figure 10.26 Post-incident pattern transfers can occur from a variety of activities, including animals. In this instance, a dog was bloodied and walked in the scene. Suspects are often quick to claim such post-incident actions are the explanation of pattern transfers, but like all evidence, they demand consideration in a holistic view.

Flow Patterns

When considering flow patterns found in the scene, one issue for the analyst to consider is distinguishing passive flows from active flows. Passive flows occur as blood flows out of a wound because of gravity and body position alone. They generally have limited investigative importance, other than perhaps pointing to movement of the body after death. Active flows, on the other hand, occur while the victim is alive. They result from bleeding and assist the analyst in positioning the victim at different locations in the scene during the event.

With regard to positioning, consider an example in which we find a flow pattern on the face of a victim. Imagine the victim is found flat on his back at the scene, but with a flow that runs up the nose. This gives the analyst a clear indication of a change in the victim's final position. Recognition of abnormal blood flow provides the analyst with specific indications of the victim's position. Blood flows will always obey gravity.

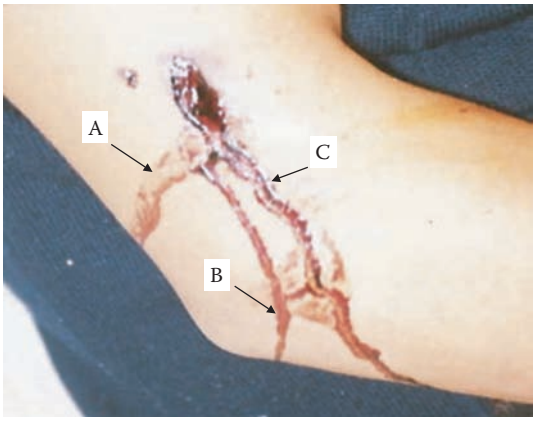

Figure 10.27 Three blood flows coming from a wound. The change in the flow patterns helps us understand that a change occurred in position of the victim's arm as the flows occurred.

Case Example — Flow

During a millennium celebration a tactical team engaged two young men, whom they reported as armed. One of the young men was shot multiple times in a stairwell. In considering the officers stories, it was reported that the young man stood at the top of the stairwell and had an AK-47 rifle raised and pointed down at the officers. There was no evidence, however, that the weapon had been fired in any fashion.

Figure 10.27 is one of the many wounds the young man received. From this wound, three flows emanate. One flow runs down the upper arm above the elbow (labeled A). Out of this flow, a second flow runs down to the lower arm, just below the elbow (labeled B). A final flow runs directly from the wound to a point further down the lower arm (labeled C). Sequentially, Flow A must precede Flow B because B initiates out of A. Flow C must be last as the flow's margins are intact from the wound along its entire margin and this flow is consistent with the final position of the victim.

Flows B and C can both be explained by the victim's final position. However, Flow A demands the upper arm was held in a position that was up, with the long axis of the arm somewhat parallel with the ground. This flow, in combination with a number of other stain patterns and physical evidence, although not establishing the man was pointing a weapon, was certainly consistent with that possibility. There was no way to establish that the young man was holding the weapon, but the physical evidence including these flows did not refute the officer's statements.

An additional consideration is the interruption of flow patterns, which may also assist the investigation. The point of interruption will often show pattern transfers of the object causing the interruption. Stoppage of the flow (congealing of the blood) may also indicate sequencing and passage of time between the flow, the interruption, and the subsequent removal of the interruption.

Pools

The analyst will find many instances of pools within the scene. By considering the drying and clotting time of blood (discussed later in this chapter), and by estimating the amount of blood, the analyst can define information about the overall incident.

Drying and clotting issues revolve around the passage of time since the bloodshed, which can often be significant. Another common issue raised about blood pools is the total volume represented by the pool. This is particularly true in instances where no body is present. At issue is whether the wounded individual could survive the wounds indicated by the volume lost in the scene. There are instances in which cases were adjudicated without a body, in part because the blood volume made it clear the individual, without medical intervention, was dead.

Such estimations are exactly that, estimations. Any attempt to define this volume must consider the surface characteristics, including its absorbency, the depth of the clot or congealed blood on the surface, and the leveled nature of the surface. Such estimations require corroboration using experimental methods, which consider all the factors just listed.

Lee and co-workers developed four methods of considering this estimation. All of the methods are based on the dry weight of bloodstains. They established a dry weight constant (0.4167 ml/mg) which they simply multiplied by the weight of the dry blood crust present in the stain. The most difficult part of their process is eliminating the weight of any substrate on which the dried crust may be present. Three of their four methods included:

1. Removing and weighing the actual blood crust present on nonabsorbent surfaces and multiplying that number by the constant.
2. Weighing the substrate and blood crust, determining a weight, of the substrate alone, subtracting this weight, and then multiplying the remainder by the constant.
3. Determining the area of substrate covered by the blood, weighing a single unit (e.g., a square centimeter), and then multiplying by both the constant and the total area.[5]

Another method for estimating blood volume is a wet volume estimate in which the analyst attempts to create a similar-sized pool. The first step is to measure the overall dimensions of the stain in question and define the total area within the stain. It is best to use the same substrate in an unstained area. The analyst then pours whole blood onto the surface in a slow and methodical fashion (see Figure 10.28), all the while monitoring the overall stain size as it develops. The analyst then measures the test stains (several tests may be necessary) defining their total area (see Figure 10.29). The comparison of the area encompassing the standards will provide the analyst a rough estimate of the volume of blood present in the questioned stain. The weight of the bleeding victim on the surface, as well as anyone who might have stepped into the pool, can further disperse and enlarge the pool and should be considered in the analysis. Although certainly not absolute, these estimations of blood volume, wet or dry, do at times serve the investigative process.

Wipes, Swipes, and Contact

Contact stains to include wipes and swipes can be quite helpful on occasion. As discussed in Chapter 7, these patterns suggest the direction of motion, which aids the analyst in reconstructing events. Just as important in some situations is the recognition that some form of contact occurred in the first place.

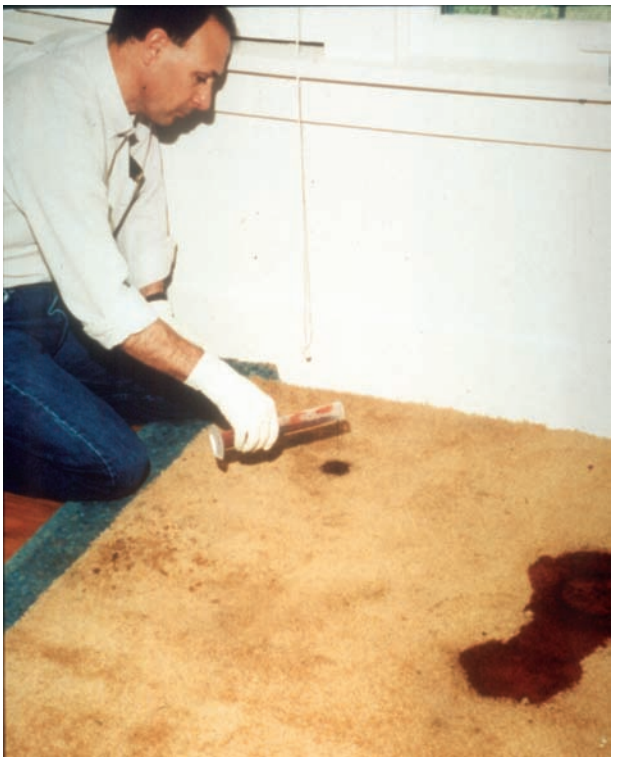

Figure 10.28 To use a wet volume estimation, the analyst creates a similar sized stain on a similar surface. Blood is added slowly and the analyst monitors the size of the stain. This is done in order to match the general dimensions of the questioned stain as closely as possible.

Figure 10.29 The analyst then measures the total area evident in the standards. This figure is compared to the area in the questioned stain. This comparison in correlation to the known volume of blood used to create the standard allows the analyst to estimate roughly the volume of blood in the questioned stain.

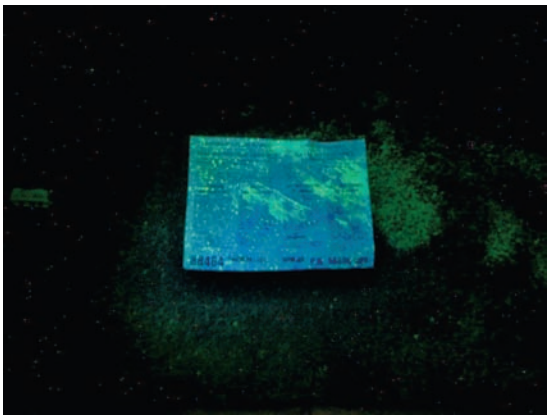

Figure 10.30 A portion of an electric blanket that was tucked in beneath the mattress when police arrived. Some very limited bloodstains could be seen on the label, but when enhanced using fluorescein it was quite apparent this area had been in contact with blood. This helped support a belief that the scene was staged.

Case Example — Contact

A woman returned home from the grocery store to find her husband stabbed to death in their bed. He was beneath the covers after receiving multiple stab wounds that were not inflicted through the bedding. During crime scene processing, the investigator noted that an electric blanket was completely tucked in at the base of the bed. Blood (still red pigmented) was located on the label of the electric blanket, which was on that portion of the blanket that was tucked in. The blood was determined to be that of the husband. When this area was enhanced, it became apparent that some form of bloody contact occurred (see Figure 10.30).

The wife was an early suspect, in part due to her behavior, her claims, and indications of a staged burglary scene. The presence of the husband's blood on the portion of the blanket that was tucked in certainly did not support her story. The fact that the killer had taken the time to tuck the electric blanket in at the foot of the bed lay in stark contrast to the rest of the bedroom where drawers had been pulled out and left. Once again, in and of itself this stain simply showed contact, but in the context of the scene and story it was significant in corroborating that the scene was staged.

Blood into Blood

The characteristic pattern of blood dripping into blood is at times significant. These patterns occur when a blood source, typically a bleeding person, remains in place long enough for dripping to occur. The pattern can present two distinct features: random satellite spatter surrounding the pool, and a fan shape evident on adjacent vertical surfaces, if present.

Blood droplets as they impact into a liquid pool form the large blossom structures discussed in Chapter 5. The satellite spatters that detach from the blossoms are projected outward from the pool. They create small (1- to 2-mm) spatters that will show evidence of varying angles of impact. The spatter may be deposited out from the pool for several feet. Because of the rolling motion that may occur in the liquid pool (resulting from the droplet impacting the liquid), such satellite spatters are projected out from the pool in random

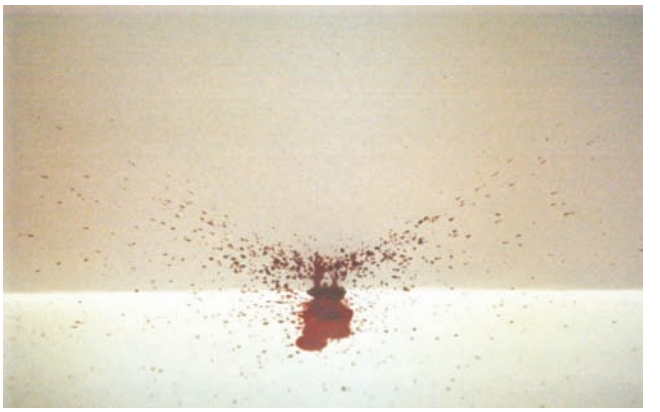

Figure 10.31 An exmple of a drip pattern on both vertical and horizontal targets. On the vertical target, the v-shaped void results near the pooled blood. All about the horizontal target are small random spatter.

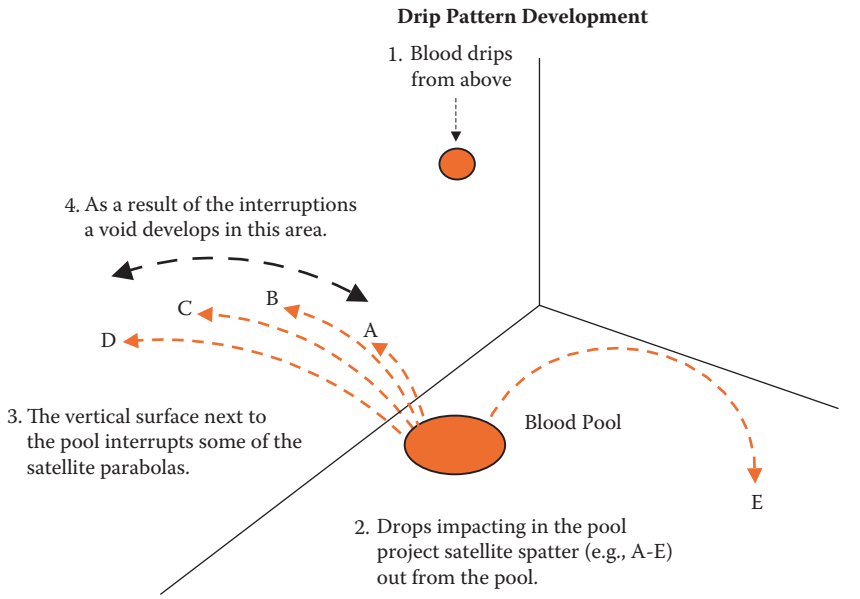

Figure 10.32 Drip pattern development on the adjacent vertical surface. (1) Blood dripping from a source impacts a static pool. (2) The impact causes satellite spatter to be projected out from the pool in every direction. Allowed to follow its natural parabola, the spatter projects away from the pool (E). (3) The droplets that strike the adjacent vertical surface have their individual parabolas interrupted. (4) The closer to the target, the sooner the parabola is interrupted (A,B). Droplets impacting the wall at more acute angles travel farther and thus attain a greater height before they impact (C,D). This causes a distinct arced demarcation in the pattern.

directions. The resulting stains will show this random directionality. Figure 10.31 is an example of a typical drip pattern.

If an adjacent vertical surface is near the pool and drip, a very distinct pattern often occurs on the vertical surface. As the droplets detach from the blossom structure they follow varying parabolas that the vertical surface will interrupt (see Figure 10.32). Obviously, the closer the vertical surface is to the pool, the earlier in the parabola the interruption

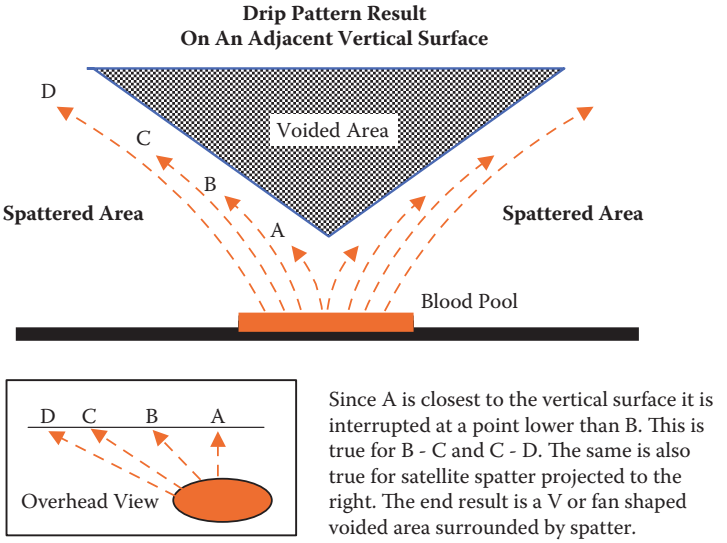

Figure 10.33 As a result of these interrupted parabolas, the spatter pattern that results will resemble a "V" or "U" shape with a voided area in the center.

will occur. Thus, the pattern evident on the vertical surface will show a voided area that resembles a "V" shape (see Figure 10.33). The bottom of the "V" will be the point where the surface was closest to the dripping action.

Blood into blood patterns may suggest the presence of a bleeding individual at a specific location for a few moments. Although it is difficult to estimate how long this period was, the delay at that point will be evident. This contrasts with a blood trail, which is evidence of continuous motion. Care is certainly in order when trying to establish a specific source of the blood into blood pattern; but if there is an evident replenishing source of blood, the pattern is most certainly associated with an injured party.

Altered Stains

You may recall from Chapter 3 that the authors did not include altered stains as a specific classification category. This is because altered stains occur across every type of pattern. Alteration may occur because of clotting, drying, dilution, or through some form of interruption such as a void. These alterations are found in flows, pools, spatter, and patterns of nearly every nature. Just because the alteration is not included as a classification does not mean altered stains are not important. Altered stains can be of great assistance in understanding the events that are ongoing in the scene.

Voids

Voids are typical in many situations, but are often encountered in spatter situations. Between the impact point and the location where we find the spatter pattern (the primary target), it is always possible that some secondary target was present or intervened. This will result in a lack of spatter in a specific area of the pattern on the primary target.

Figure 10.34 After receiving one gunshot wound, the victim fell to a position on the floor and the hat displaced from his head. A second shot was fired, producing a distinct ejection of spatter (a double shot impact event). The voided area behind the cap and the spatter on the inside surfaces helps us understand the location of the item when the event occurred.

Figure 10.35 A void in a spatter pattern. This photograph shows two important considerations with regard to voids. First, the sharper the demarcation the more confident the analyst will be that he is viewing a void. The correlation of the void to the magnifying glass is quite apparent. Second, the item that created the void should have similar staining unless it has been cleaned or significantly altered. If the magnifying glass was the object creating the void, it will have the same level of spatter as the pattern itself. (Photograph courtesy of Sandra M. Roberts, Eugene Police Department, Eugene, OR.)

This effect, sometimes referred to as ghosting, may indicate the nature or shape of the secondary object. If this object is known, it may help identify specific movements, or lack thereof, of these objects in the scene. As an example, consider Figure 10.34. A double shot impact spatter event occurred to the right of the baseball cap, when the victim was shot twice with a 45-caliber pistol. Based on the voided area on the wall behind the cap and the spatter on the cap itself, it is apparent the cap acted as a secondary target. Figure 10.35 depicts another void in spatter.

In correlating the object that produced the void, there is an expectation that it will be similarly stained (in both type and quantity) as the target was around the void. The only valid exception would be if the object were cleaned or significantly altered in some other fashion.

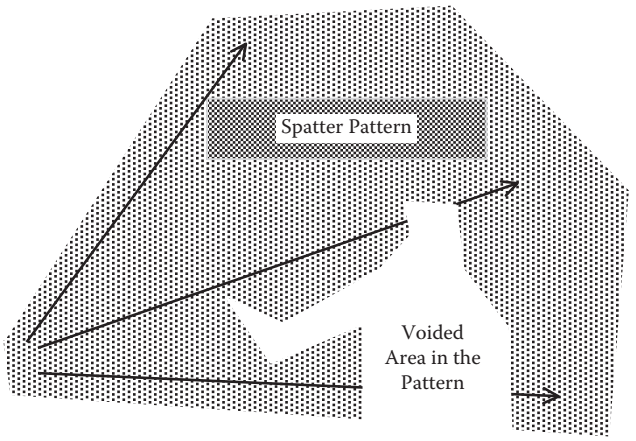

Figure 10.36 Interrupted pattern with an obvious void. Voids of this nature are easy to identify as the pattern clearly continues beyond the limits of the voided area. Often the shape of the void will assist the analyst in identifying the object that intercepted the spatter or blood.

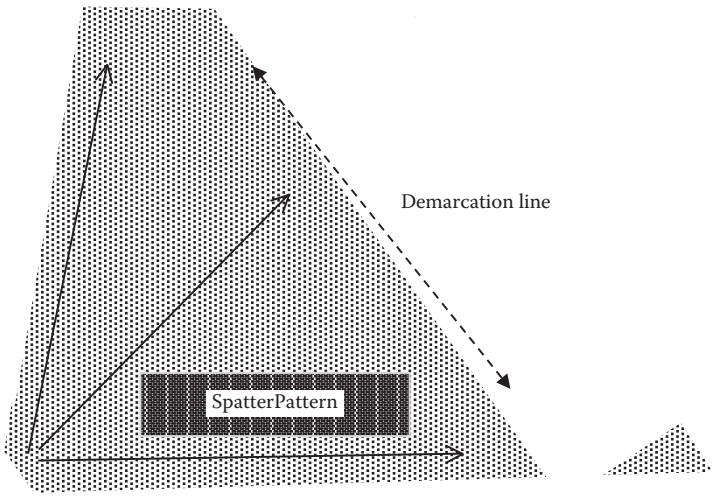

Figure 10.37 A less evident void situation. In this instance, we may still be viewing a void (e.g., the area to the right of the demarcation line) but it is also possible we are simply viewing the natural termination of the spatter pattern. In a pattern of this nature, decisions relating to whether this is a void require a level of caution.

It is important to caveat the consideration of voids by saying there is a big difference between a spatter pattern that is interrupted and then continues and a pattern that simply stops (see Figure 10.36 and Figure 10.37).

Voids may occur in either instance, but in the latter, the analyst may be less confident that he is viewing an actual void. If the pattern ends abruptly with a distinct linear demarcation (as observed in Figure 10.34) it is a true void. If no distinct demarcation is present, it may simply be the natural end of the pattern.

Voids are often functional for establishing position of the victim, assailant, or other objects at the time of the event. For example, voids on the clothing may establish that a hand or arm was up or extended. In such instances, arms and legs may shield the clothing

Figure 10.38 A victim present on the floor surrounded by a pool of blood.

Figure 10.39 When the victim in Figure 10.38 is removed, there is a clear void present. Note where the right arm was positioned, the pool developed subsequent to her positioning.

and skin behind them from the spatter event. The resulting voided areas may provide the analyst with a clearer picture of the individual's body position.

Case Example — Voids

Figure 10.38 and Figure 10.39 show a case involving a woman killed and left on a floor. The resulting voids in the blood show two distinct things: (1) The position of the victim's arms and torso when left, and (2) the victim was present for an extended period after blood loss, producing the thickened and demarcated outlines.

Clotting

Alteration of the stain as a function of clotting gives the analyst an indication of the time that passed between bloodshed and the observation of clotting. Anita Wonder defined three stages for clotting. She referred to these as clot initiation, clot firmation, and clot retraction.

According to Wonder, initiation starts between 10 s and 1.5 min after bloodshed. This is a natural result of the blood's exposure to the outside environment. Wonder described clot firmation as the point where, if disturbed, no flow-back will occur. This begins anywhere from 5 to 20 min after bloodshed. Clot retraction, which Wonder defined as serum separation from the fibrin mass, begins anywhere from 30 min to 1.5 h after bloodshed.[6] Figure 10.40 shows a pool with evident serum separation and clotting.

Obviously, categorizing the stage of clotting is a parameter decision. We strongly caveat the times involved because clotting time is affected by issues of temperature, humidity, and the surface on which the blood was shed. Laber and Epstein found similar clotting times as Wonder, ranging from 5 to 40 min. The primary environmental factors they considered important to the clotting process include surface of the target and temperature.[7]

Case Example — Clotting

A young mother and her child were found shot. The child was shot twice, once in CV-2 and once in the head. In the hallway where the child was found were two pools of blood. One pool of blood soaked through the carpet, carpet pad, and into the sub-floor. This established a passage of time between rolling of the victim from this position and the second shot. In the

Figure 10.40 A pool of blood showing both clotting (the congealed dark mass) and serum separation (the pinkish colored flow that moves out of the pool to the left and down the wood floor).

Figure 10.41 An area of congealed blood, which holds a child's handprint. As the flow occurred, the blood congealed while the hand was present in it. The hand was then removed. This type of pattern defines evidence that points both to the nature of the object that caused the pattern and to issues regarding timing and sequencing aspects. (Photograph courtesy of Edmond Police Department, Edmond, OK.)

second pool was a congealed mass showing the handprint of the child (see Figure 10.41). This second pool indicated the child was shot and bled in this second location while her hand was in this position before being moved by the individual who found the bodies.

Drying Time of Blood

Drying time and skeletonization are both important alterations of blood that aid in the analysis. Of concern is the drying time of both droplets and larger volumes of blood. Pex and Hurley established that a ring always appears on the edge of a wiped bloodstain, if the wipe occurs within 50 s after the blood was deposited.[8] In some instances this ring may appear earlier. This effect is referred to as skeletonization. The dried outer ring evident in the stain may not wipe away even in situations where the stain is vigorously wiped.

Depending upon environmental factors and the surface on which we find the blood, a single drop may take between 20 to 90 min to dry completely. The skeletonization effect, however, consistently occurs no later than 50 s after initial bloodshed (see Figure 10.42).

In terms of individual bloodstain drying times, environmental factors are always important. Air temperature alone has a limited affect on drying time of individual drops, although significantly colder temperatures will increase drying time. Surface temperature can affect drying time. In the case of a hot surface temperature, drying time is reduced. Airflow across the drop, however, has a dramatic affect. The Florida Department of Law Enforcement's early experiments indicate that increasing airflow across the surface where a single blood drop was deposited can change the drying time from as much as 90 min to as little as 20 min. Another aspect of their effort is the volume present and how spread out it is. Single drops of blood produced from a consistent volume were dropped from increasing heights, which of course resulted in an increasing stain size. The larger stains dried faster

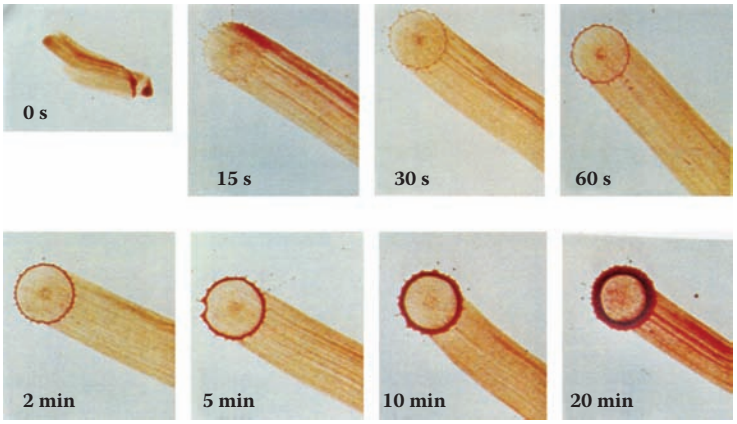

Figure 10.42 The skeletonization effect in a blood droplet. Each droplet was deposited and then wiped through at the time indicated. Note that 30 s after deposit a ring is present on the outside boundary of the stain. At 60 s, the ring is readily apparent. This effect is known as skeletonization and allows us to distinguish between stains that were disturbed immediately after deposit and those that were disturbed later on. The time necessary for this ring to appear is independent of environmental factors. The time it takes the droplet to dry completely, however, is dependant upon the environmental factors.

than the smaller stains. The obvious correlation is the more surface area exposed for a given volume to the environmental conditions, the quicker the drying time.[9]

To establish actual drying times of droplets or other volumes, the analyst must consider the scene's environmental conditions. By matching these conditions during experimentation, the analyst may be able to define with some level of confidence the drying times of stains of different sizes. Even if lacking this knowledge, the skeletonization effect by itself defines whether a specific pattern or stain was disturbed immediately after its creation.

Drying time of volume accumulations (e.g., large pools) also requires experimental effort. In many instances, the pool simply is not dry at the time of police discovery. So not being completely dry and having to evaluate how dry it was represents a subjective call up front. The information derived from the clotting of the accumulation is probably of greater value to the analyst than attempting to define a partial drying time.

Dilution

Another form of alteration occurs when whole blood becomes diluted. The most often encountered occurrence of dilution is with water, when blood is washed up. For example, Figure 10.43 depicts several diluted blood drops and a diluted flow in a sink. Their presence indicates that subsequent to the wounding of the victim someone utilized the sink to wash themselves or some object.

Summary

It is not enough just to know the basic nature of a bloodstain (e.g., its classification). In some fashion, the analyst must understand what the pattern can tell him and how that information may be of value in the context of his particular crime scene.

Figure 10.43 Diluted stains. The stains on and in this sink were created by blood mixed with water. Alteration by dilution can aid in understanding that some other action (the diluting event) occurred subsequent to bloodshed.

Gardner recalls a recent interaction with an arguably senile judge, who after looking at a picture of an arterial spurt in a book, demanded to know how the book pattern might tell anyone about where a suspect in the court case in question was. The pattern in the book did not. But the lack of arterial patterns in the scene for which this judge was sitting in judgment told anyone willing to listen quite a lot regarding what was being claimed in that courtroom. What a pattern can or cannot tell the analyst is a function of time and surroundings; the context in which we find the pattern is everything! As with all evidence, no pattern tells the whole story of its creation every time, but every pattern tells some part of the story. When we combine what all of the patterns tell us in their totality, we have a rather distinct part of the story. The question is this: In the context of this scene, does that part of the story aid us or the jury in our understanding?

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Bloodstained Clothing Issues

11

It is rare indeed for the analyst not to be confronted with various items of bloodstained clothing or fabrics during an analysis. These are likely to include the victim's or suspect's clothing and oftentimes bedding. Clothing and fabrics do not significantly alter the analyst's approach to bloodstain pattern analysis, but they do create specific concerns. These concerns include:

- Applying good on-scene documentation for clothing
- Overcoming poor collection/documentation procedures
- Differentiating contact stains from spatter stains
- Understanding the limitations of directionality and impact angle analysis
- Recognizing pattern transfer issues

Applying Good Clothing Documentation Procedures

Of all of the surfaces that may be bloodstained in a given crime scene, one surface stands out as routinely being altered, damaged, or destroyed before it is properly documented. That surface is the victim's clothing. On scene, the clothes often hold important information and patterns; these can include spatter, pattern transfers, or distinct flow patterns that show some orientation of the victim. The list is endless. As found *in situ*, these patterns may be marred in some fashion by exposure to blood pools or post-incident bleeding at the scene. Granted, these situations may damage some of the value of the patterns, but as a rule, such marring is limited. Lacking any other alteration, these patterns can still prove fruitful in understanding what occurred during the bloodstain event. Unfortunately, not all of these patterns are documented on scene prior to movement of the victim.

The dead victim is always problematic. Law enforcement authorities have responsibility for the scene, but the victim's remains are the responsibility of the coroner or medical examiner. As such, crime scene investigators are generally limited in how they can manipulate a body. As a result, the old "bag and tag" mindset is often in place. Once basic scene documentation is complete, the body is bagged and removed, the intent being to examine it fully at the morgue during the autopsy. That is all well and good and certainly necessary, except that when placed in a body bag, it is routine for additional passive blood flow to occur. This passive blood combined with the movement and contact between the body bag and remains results in excessive saturation staining to clothing on the victim. What started out as a relatively clean victim at the scene becomes a literal bloody mess when removed from the body bag at the morgue (see Figure 11.1 and Figure 11.2). Any patterns that were present on the victim's remains (e.g., flows on the face, spatter on the hands) or patterns that were present on the clothing of the victim can be marred beyond recognition. Additionally, new patterns in the form of heavy saturation stains, flows, or even spatter may appear as a result of manipulation. If not recognized as post-incident artifacts, these patterns will cloud the analyst's overall understanding.

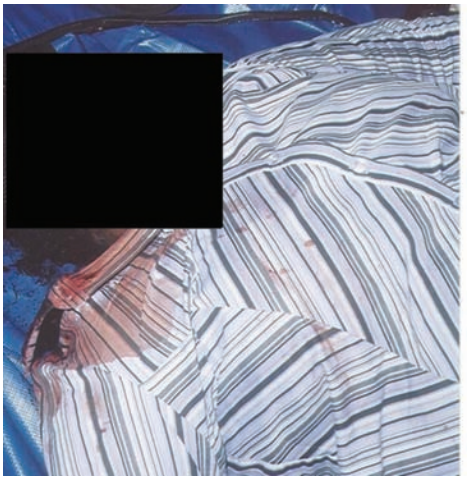


Figure 11.1 The condition of the clothing at the scene is important to document. This condition will change with time and manipulation of the victim. Compare the condition of the blouse in this photograph with its subsequent condition shown in Figure 11.2.

Figure 11.2 The condition of clothing after transport of the victim and examination at the morgue is anything but pristine. New patterns (primarily saturation stains) are produced and mar other patterns of interest. It is imperative that the clothing be documented at the scene.

The loss of patterns on clothing can be eliminated though some simple documentation steps. First, the body must be examined on scene for evident patterns of interest. When observed and before significant manipulation by EMS (if that is possible), these patterns should be photographed. Such patterns may include patterns on the clothes and/or the body itself. Patterns that are immediately evident (those on the exposed aspects of the remains) are simple enough; they should be recognized and documented as an integral part of the scene documentation with both evidence establishing and close-up photographs. The

bigger issue is when the body is ready for release. Those areas of the body that are down and not viewable must be examined before releasing the body to the morgue. The body should be turned and the remaining clothing carefully examined and documented. Keep in mind that patterns on any portion of the clothing that is on or near pressure points on which the remains will rest at the morgue are as good as destroyed. If they are not documented on scene, there will be no further opportunities and the information in the patterns will be lost forever.

If patterns of significance are encountered by the analyst, it is not taboo to simply request permission from the medical examiner to recover the clothing before the body is bagged. Whether this request is granted, at the very least the analyst has made the effort to protect the evidence the best he could. Such a request is more likely to be approved if there is some level of discussion before the need arises. Prior coordination will help the ME's office recognize the need for such collection and help eliminate any doubts that the ME's interests will be protected in the process. Without question, clothing collected on scene will need to be examined by the ME in order to correlate defects in the clothing to wounds on the body.

Clothing removed from the victim by EMS on scene or by doctors at the hospital is also important. Obviously such clothing has been manipulated and damaged, but the bloodstain patterns themselves may still be evident and of value. There really is no reason, other than laziness, for these clothes not to be recovered. Unless they are literally stolen, the crime scene investigators have a duty to pursue and collect the clothing. Excuses that the clothes were mixed in with the trash or thrown away should never be accepted. The victim's clothing offers critical evidence and every reasonable effort to recover the clothing should be pursued.

Although not a direct function of the clothing examination, one photograph related to it and routinely forgotten is the "after removal" photograph. Basic crime scene procedures will generally ensure photographs of the body in place in the scene, but when the body is released most of this effort is already accomplished. Thus, when the body is removed, no one considers photographing the area from where the body was removed. The presence of staining and patterns or the lack thereof can have a significant influence on the bloodstain pattern analysis. As the body is turned to photograph the clothing or when it is removed from the scene, be sure to properly document the areas beneath the body as well.

The recovery and documentation of any suspect's clothing is also important. Far too often the suspect's clothes are not taken, merely photographed (and not photographed well), leaving the analyst with more questions than answers (see Figure 11.3). With the current emphasis on DNA, initial responding officers are less likely to ignore such evidence, but it is still common to encounter officers who do not seize clearly bloodied clothing. Even if there is no immediately visible blood, at a minimum, clothing should be examined closely for any patterns or traces that are inconsistent with any claimed activity for any individual who discovers a victim. Whenever possible and appropriate, the suspect's clothing, visibly stained or not, should be seized for proper examination at a later time using magnification and proper lighting. This also applies to any person who may have been in contact with the victim prior to the arrival of authorities or who was in close proximity during the bloodshed incident.

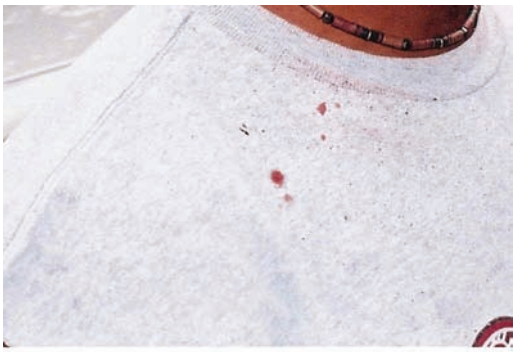


Figure 11.3 This individual was involved in a shooting incident. The pattern on his T-shirt suggests it is spatter; however, despite the obvious bloodstains, the initial responders did not take this clothing and it literally walked away from the scene. Without the clothing to examine and validate the nature of the stains, no conclusions can be drawn.

Overcoming Poor Collection/Documentation Procedures

If appropriate on-scene documentation efforts are not accomplished and a request is neither made nor granted to recover the clothing, how can the analyst overcome marring or recognize what patterns are post-incident? Depending upon the level of marring, it may still be possible to pull information from such clothing. If the saturation staining is not excessive, underlying patterns may still be visible. As a rule, however, marring by saturation cannot be overcome. Once destroyed, there is no functional means to remove or look through the saturation and recover the pattern information. This is an area ripe for research, and perhaps in the future some combination of chemical and alternate light source wavelength will make it possible to see through the saturation staining and evaluate any patterns beneath. For the moment, prevention of post-incident saturation is the only course of action. On the other hand, the analyst can usually recognize post-incident patterns. This is done by using any *in situ* photographs that are available and comparing them to the current condition of the clothing.

To make this distinction the analyst should seek and find any and all photographs of the area on the clothing in question (keep in mind that these areas are often captured on other crime scene photographs, such as close-ups of items of evidence around the body). The photographs used by the analyst should include only those taken on scene before significant manipulation of the remains. It is understood that these photographs will not allow detailed views, but analysis of the stain from the photograph is not the issue, recognition of its existence is. The photographs are examined from their varying perspectives in an effort to locate stains or patterns that were present on scene and associate them with landmarks (e.g., seams, defects, and buttons). The stains are then located using these landmarks on the actual clothing item. If the pattern is present on the clothing in the crime scene photographs, then the pattern itself can be examined with a level of confidence that the stain being examined was present before the removal and manipulation of the victim.

Recognizing that bloodstain pattern analysts are not always responsible for processing the crime scene, it should be evident their analysis can fall victim to the efforts of the crime scene processors. For this reason, there is an inherent responsibility to properly train the crime scene processors on documentation of bloodstain patterns, and particularly

Figure 11.4 This is the actual collection procedure used by an investigative organization looking at a homicide. All of the clothing of the victim was removed at autopsy and stuffed into this single paper bag. Not only are cross-contamination issues possible, but also post-incident artifacts in the form of additional contact staining and/or saturation are likely to result from this abysmal effort.

bloodstained clothing. The analysts should not be passive players. They should do everything in their power to see that proper training is given to and appropriate techniques are employed by the crime scene investigators. Failing to take such steps may result in receiving evidence in a very inappropriate form that will ultimately handcuff the analysis (see Figure 11.4).

Distinguishing Contact from Spatter on Fabric

Blood has a medically recognized adhesive quality; because of this property, it should not surprise us to find bloodstains on those who discover victims of crime. Such witnesses may touch, cradle, or move the victim in some fashion, which in turn will result in the transfer of blood onto clothing and skin. The likelihood of such transfers is not lost on the perpetrators; they too claim incidental contact as the source of stains found on their clothing. The reader may recall Dr. Ziemke's reminder about the necessity of recovering the clothing of those who discover the victims of beatings and shootings. That concern is still true today because the analyst can often corroborate or disprove statements of such individuals using the bloodstains present on their clothing.

One of the more critical considerations made using clothing is distinguishing contact from spatter. In certain situations it is possible for very light contact of a bloody object to mimic or appear to be a spatter stain. When presented with such a stain, it is necessary for the analyst to distinguish between spatter (created by dynamic events) and stains created by incidental contact. When contact stains are found as a whole pattern or a large saturation, the differences between contact and spatter are very easy to distinguish; however, in

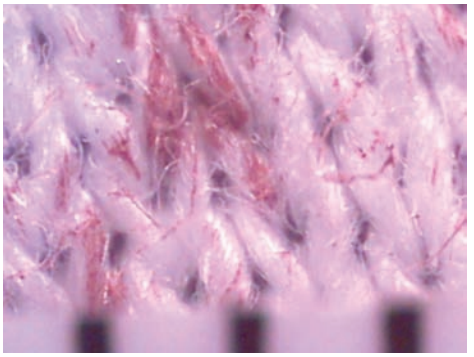


Figure 11.5 Contact staining of cloth under 60× magnification. Direct compression contact by a bloody item generally creates a saturation stain that is easily recognizable as contact, but light contact may mimic spatter. Under magnification, however, the contact stains appear primarily on the top surface of the weave because the nature of contact is very often some form of lateral motion (e.g., a swipe).

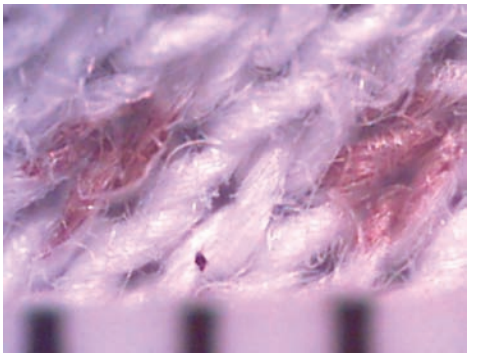


Figure 11.6 Spatter stains on cloth under 60× magnification. Spatter is projected into the cloth, so not all of the stains will be on the top surfaces. Note the two stains have blood deep into the depths of the weave. Not every spatter stain on cloth will demonstrate this appearance, but the presence of several will validate that the pattern is spatter and not contact.

the case of very limited contact, the resulting stains are quite small and their true source may not be immediately evident.

Even in the case of these very small contact stains, the analyst can often make this distinction on fabric. Remember, the two stains result from distinctly different actions. One is projected onto the target, while the second merely makes contact with the target. When viewing the contact stain under low magnification, the analyst will observe blood traces on the upper weave of the fabric. As the stain is generally the result of a light swipe (with lateral motion), the deeper areas of the weave are often left untouched by the blood source. Even in situations in which there is a compression contact with saturation, areas within the weave may still be free of blood. Figure 11.5 demonstrates this appearance under 60× magnification on 50/50 cotton/polyester material.

Spatter, on the other hand, strikes the clothing in a projected fashion. The small droplets impact into the weave, rather than brushing against it. When viewing a spatter stain, the lower levels of the weave are likely to exhibit staining. Figure 11.6 shows two projected spatter stains on 50/50 cotton/polyester material. Note the distinct differences between the stains in Figure 11.5 and Figure 11.6. Pex and Vaughan found this type of examination particularly useful in situations involving gunshots.[1] In their efforts to distinguish between contact staining and back spatter situations, they found that small back spatter droplets were often evident deep in the weave of a fabric.

The problem for this particular examination is that some contact may be sufficient to produce larger stains that saturate the weave (unlike those observed in Figure 11.5) and not every spatter drop impacts into the junction of a weave. Spatter drops are so small that they can and do impact on upper surfaces of the threads. The stains resulting from such impacts will appear on upper surfaces as well, so there can be distinct similarities between the staining seen in contact and that seen in a spatter event. In order to make the call with some level of confidence, the analyst should seek several clear examples of spatter

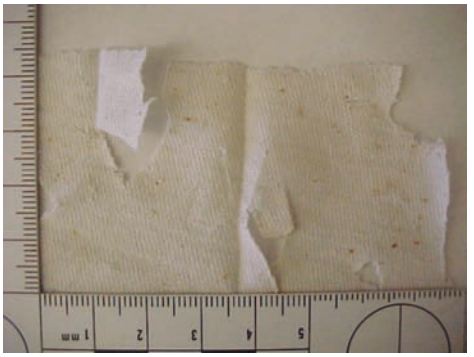


Figure 11.7 A stain on a piece of cotton T-shirt that upon initial evaluation was considered to be spatter. The T-shirt was recovered from a man who was suspected of killing another person with a shotgun.

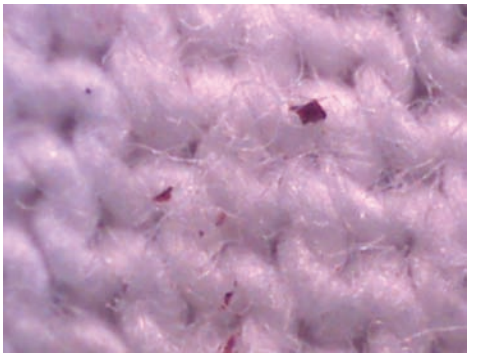


Figure 11.8 The "spatter" viewed under 60× magnification. The stains were clearly the result of some mechanism that occurred after the blood coagulated. DNA analysis added another wrinkle to the initial evaluation. The stains are the product of two DNA sources, the primary was the owner of the T-shirt, and the secondary source was the victim. Whatever the actual method of creation, these stains were not the result of a spatter event involving fresh blood.

that have been deposited into a weave juncture. In the weave the differences between the two stains will become clearer. The presence of such stains deep in the weave allows the analyst to distinguish the stains as projected stains rather than some form of contact. In a contact stain, lateral movement is very often seen in any transfer. It is very difficult to make contact with a straight in and out movement with no lateral motion. This can be done in controlled experiments in a lab setting, but in an actual violent crime, evidence of this lateral movement is usually present. As always, it is important to contrast the condition of the scene with the clothing items. Is there evidence of an event capable of creating spatter on scene, one consistent with that found on the clothing? Ultimately, if clear examples of contact or spatter are not present, the analyst should not be afraid to say, "I don't know."

Contact and spatter stains are not the only form of stains encountered in such an analysis. Figure 11.7 is an interesting example of a stain that appeared on cursory view to be related to a spatter event. The stain certainly gives the appearance of meeting the "misting" definition and looks to be spatter. The stain was deposited and recovered from the right chest area of a T-shirt, taken from a suspect in a shooting. The victim was shot once in the head. During an examination using proper lighting and magnification, it became apparent the stain consisted of coagulated material (see Figure 11.8). A subsequent DNA analysis was also interesting. The stain was a mixed stain. The primary contributor was the suspect and the secondary contributor was the victim. Although no specific mechanism of creation could be identified for the stain, what was evident from examination was that the stain did not result from spatter created as a result of the gunshot.

Recent claims suggest that the analyst must use magnification of at least 100 power in order to be confident when trying to distinguish contact from spatter, but empirical experience shows any magnification 20 power and up is more than adequate to see the described differences. The analyst should not use any power higher than 50 to 60 because

Figure 11.9 Painted fibers occur in a variety of situations including simple contact and spatter deposited on wet fabric. The fiber will appear coated with blood. What probative value a "painted fiber" provides to the analyst has yet to be determined.

above that magnification level, the specific details for which the analyst is looking are lost.

In 2005, the issue of contact vs. spatter was raised in a highly contentious murder trial. A series of eight stains were found on the T-shirt of a murder suspect, which he claimed were the result of contact when he discovered the victims (his family). In the initial trial, a concept known as "painted fibers" was raised by the defense experts and presented to the court as scientific proof that the stains were the result of contact and could not have originated from a spatter event. The defense relied so heavily on the idea that the word "painted fiber" was used in excess of 100 times in front of the jury by the defense experts. This was all well and good with one exception; prior to that moment in time, no one in bloodstain pattern analysis had discussed, written anything on, or even heard the term "painted fiber." Thus, this "scientific" evidence had never been exposed to any peer review or additional research. Subsequent research shows that there are in fact "painted fibers"; however, they occur in both contact and spatter events. As such, their probative value to the bloodstain pattern analysis is questionable, at least in terms of recognizing or distinguishing contact from spatter (see Figure 11.9).

Another basic consideration regarding spatter on fabric is just how difficult it is to see. On white or light-colored fabrics, the contrast of these small stains usually makes them evident on any initial visual inspection. However, if the color of the fabric is dark, visual examination of the clothing without proper lighting and magnification may make the stains all but impossible to see. The larger the weave of the fabric, the more difficult it will be to see (see Figure 11.10). Keep in mind that blood does not fluoresce, and oblique white lighting will likely provide the best visual examination environment. Recent advances suggest that IR photography of dark clothing may provide a functional means of bringing out patterns present on such fabrics (Figure 11.11).

Directionality and Impact Angle Issues on Fabric

Surface characteristics are always a concern for the bloodstain pattern analyst because target surface affects the collapse of the droplet and thus the symmetry of the resulting stain. Various fabrics can present some interesting effects on stain shape and certainly limit the analyst's ability to understand directionality. Distortion of the stain on a fabric's surface is a function of the texture of the fabric as well as its absorption characteristics.[2] That distortion makes impact angle determination suspect. For instance, in Figure 11.12, the stains on the jean material have what appear to be elliptical shapes; however, the drops fell at 90° to the fabric. Keep in mind that the level of error for calculated impact angles on fabric is likely to be well above the normal ±3 degrees.[3] In all fabric circumstances, angle

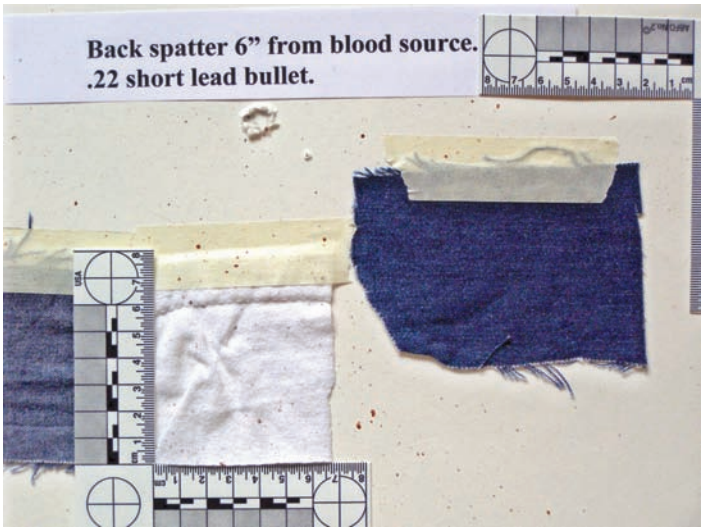
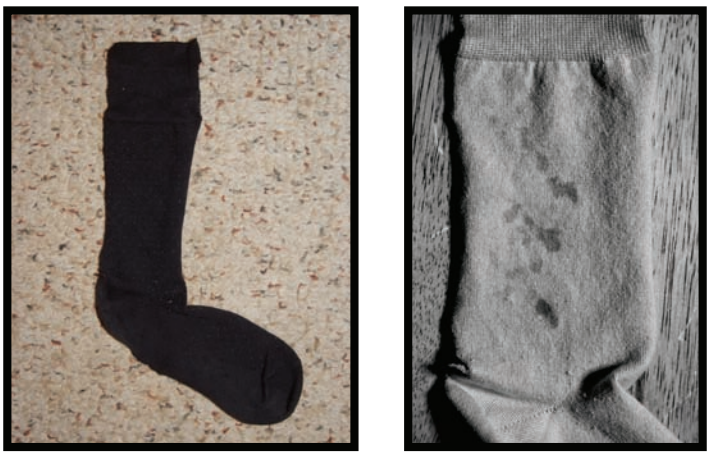


Figure 11.10 The very nature of a fabric can mask the presence of spatter. In this instance, white cotton, a cotton blend, and jean material have been exposed to a back spatter event from a weapon. The staining on the dark jean material is quite difficult, if not impossible, to see without the assistance of proper lighting and magnification.



Natural Light Photograph **IR Light Photograph**

Figure 11.11 IR photograph produced with a Fuji UVIR camera body with 60mm Nikon lens and a Pesa 89a filter. Camera set to manual mode and focus. Shutter speed set at 1/15th s and *f* 4.8. ISO 400 using ambient soft light and no flash. (Photograph courtesy of Jason Guffey, Central Piedmont Community College, Charlotte, NC.)

of impact should be reported in a general sense (e.g., the droplet struck at an acute angle) based on the overall shape, rather than offering a specific calculated angle. Certain fabrics, particularly those made up of a high percentage of polyester or nylon, and those treated with a water-resistant chemical or a fabric designed as water resistant, can produce spatter stains that actually appear rectangular. Particularly in the latter, the stains may not even remain on the clothing. Droplets can fall to the surface of the fabric, dry, and then fall off the surface without being absorbed into the material.

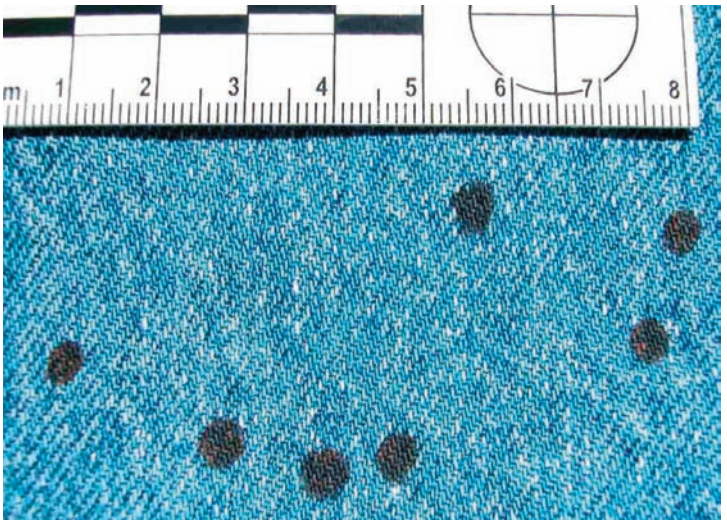


Figure 11.12 When considering bloodstained cloth, caution is always required. These stains on the jean material might suggest that the drops struck at a slight angle, but in fact, they are a product of a 90° impact. Angles of impact in particular are always reported in a general fashion on clothing or fabric items (e.g., struck at an acute angle, struck generally perpendicular).

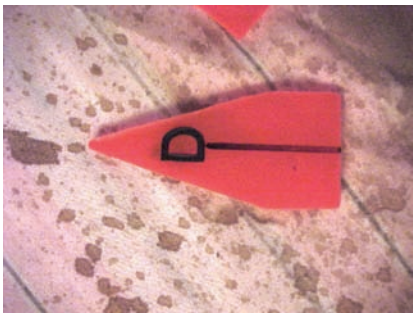


Figure 11.13 In considering directionality, these stains offer little assistance based on the shape of the stain alone. First, many are asymmetrical. Second, and more importantly, there are few if any tails or satellite spatter to define which side of the ellipse is the front and which side is the rear.

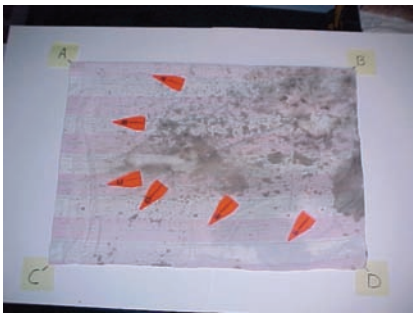


Figure 11.14 Directionality on fabric or cloth is not always a complete lost cause. If we consider the overall pattern, along with the major axis of the involved ellipses, we can still visualize the radiating nature of the spatter pattern, which defines the directionality.

If the shape of the stain affects impact angle calculations, it also affects directionality issues. Lacking in many spatter stains on fabric are satellites or scalloped edges, the characteristics that normally assist the analyst in recognizing directionality. The stains are simply ellipses (see Figure 11.13). Analysis of directionality in these instances is not completely lost, but it is more likely to be established by looking at the overall impact pattern, with a specific concern directed at its radiating nature (see Figure 11.14). Fabric to fabric, the characteristics of cloth change. The best advice is for the analyst to be sure he knows the nature of the fabric involved, either through prior experience or through testing, and to approach all fabrics warily when considering directionality and impact angle.

Pattern Transfer Issues

When bloodstain pattern analysts evaluate items for pattern transfers, they generally look for curves and distinct demarcations (something that does not appear to be naturally occurring), which suggest an object of some nature. Bloodied clothing that has been wadded up and in contact with itself can produce linear demarcations that may mimic pattern transfers. The patterns produced may be distinct curves that on first blush may suggest knives or other objects as their source. Therefore, when evaluating pattern transfers on clothing or fabric, a level of caution is always necessary.

The best method of resolving this issue is to cautiously consider any single dimension patterns (e.g., a single demarcation), and always look for multiple landmarks (e.g., multiple demarcated lines at angles to one another) in the pattern transfer. In the latter situation, the analyst can be more confident that it is a pattern unrelated to clothing rubbing against itself. The analyst should then be able to reproduce the pattern through the alleged source mechanism. Additionally, the analyst may consider enhancing the pattern with a chemical. Such enhancements, as discussed in Chapter 12, may bring out additional details in the pattern transfer, making its source more evident.

Clothing Documentation

When evaluating patterns on clothing, bedding, and other fabrics, an additional means of documenting the nature and extent of the patterns includes sketching. Some analysts have suggested that such sketches should be "to scale," but this claim is based on a lack of understanding of what "to scale" means and what it imposes on the analyst. In crime scene work a "to scale" drawing means exactly that — any measurement taken from the sketch will match a measurement in the actual scene based on some indicated scale. A level of error is always assumed, but the nature of that error is quite low. If the sketch does not match or a significant error is evident, the sketch will be attacked by opposing counsel. For this reason, most crime scene sketches are prepared in a "not to scale" format showing landmarks and evidence, as well as measurements, but without the claim that each aspect of the sketch will match directly. In this latter approach, counsel is without challenge.

Consider this issue in the situation of a bloodied piece of clothing. These items of clothing are often misshapen by being bloodied and then drying. The stretched and disfigured fabric may be torn or cut, with ragged edges. The ability of anyone to draw "to scale" each surface of such an item is asking a bit much. The task is literally impossible, given the expectation of what a "to scale" drawing is. Thus, clothing sketches should not be represented as "to scale"; they should simply be demonstrative and accurate.

Patterns of interest should be identified on the clothing sketch, with their overall dimensions or generalized position sketched and annotated (see Figure 11.15). Measurements from associated landmarks (e.g., "extending six inches to the left of the inseam") should be annotated to assist others in understanding where the pattern was observed. All of the sketches should be supported with overall and close-up photographs showing the specific details.

As will be discussed in detail in Chapter 13, the technique known as Roadmapping can be employed quite effectively to demonstrate with photographs the various patterns

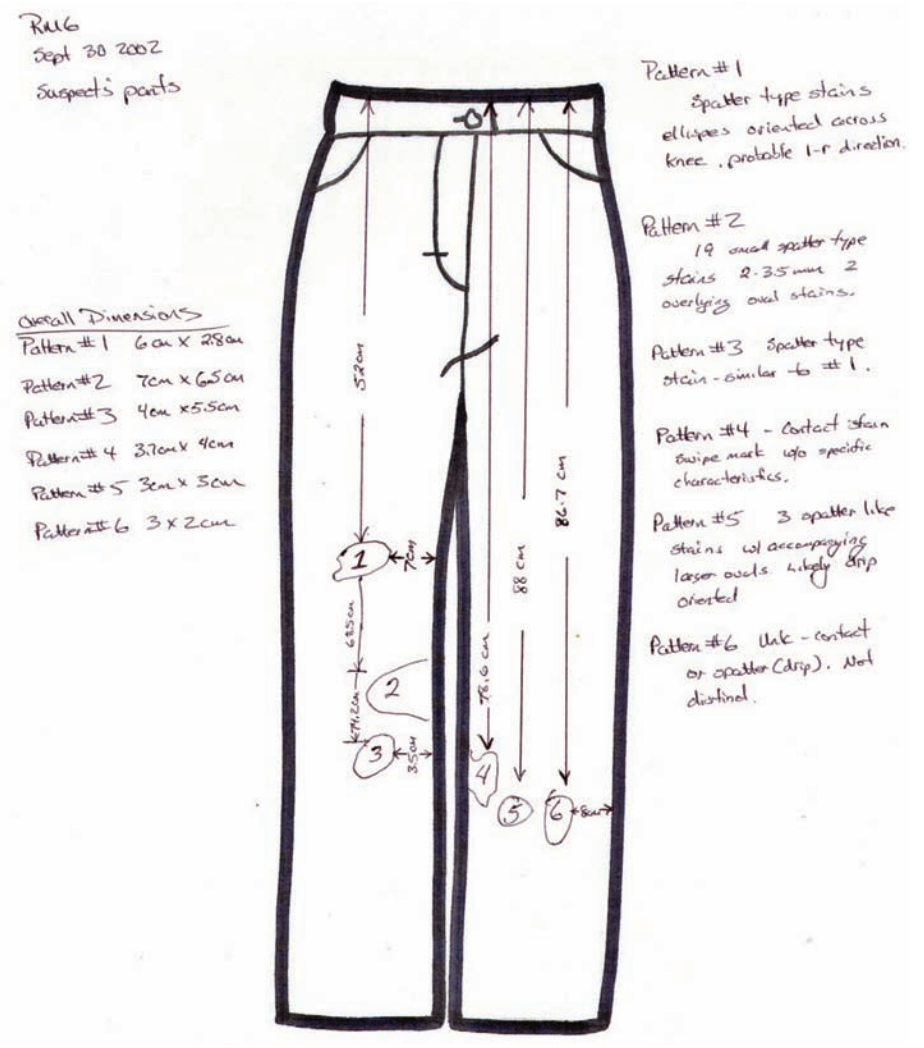


Figure 11.15 Clothing sketches should be detailed and accurate, but it is nearly impossible to create a "to scale" clothing sketch of a bloodied item. Clothing sketches should not be represented as such.

present on the clothing. In Roadmapping, some form of large readable label for each pattern is introduced and conspicuous in each photograph. Overall photographs are taken with all of these labels to show overall orientation on the clothing or item (see Figure 11.16). Of course, each close-up photograph has a label as well, thus preventing any confusion about what area or pattern is depicted in the photograph (see Figure 11.17 through Figure 11.21). If macro-photographs are necessary, the large label may need to be replaced with a smaller label (see Figure 11.22).

Summary

Fabric and clothing will certainly limit the bloodstain pattern analyst in certain areas, but such targets do not eliminate the ability to evaluate the basic patterns. A major concern

Figure 11.16 Using the "roadmapping" documentation method, overall photographs are taken of an item of clothing, which include appropriate scales and labels indicating where specific stains are on the item.

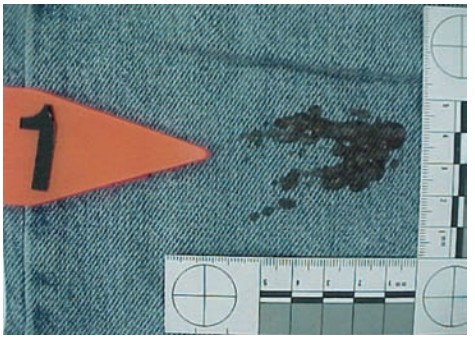


Figure 11.17 This is a close-up photograph of Stain #1 from the item depicted in Figure 11.16.

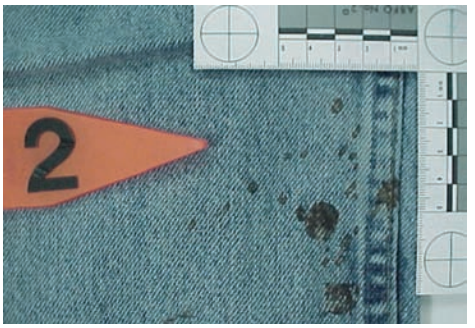


Figure 11.18 This is a close-up photograph of Stain #2 from the item depicted in Figure 11.16. Each stain is shown in its entirety as close up as possible.

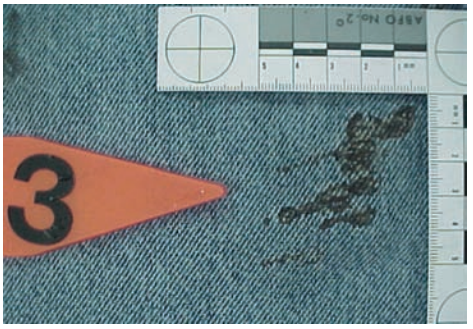


Figure 11.19 A close-up photograph of Stain #3 from the item depicted in Figure 11.16.

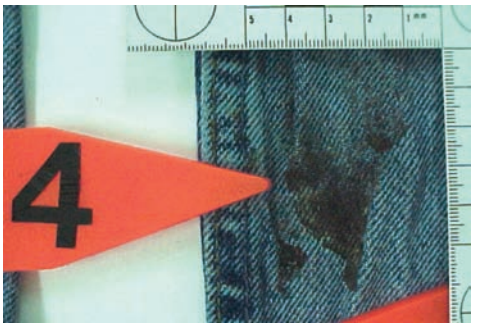


Figure 11.20 A close-up photograph of Stain #4 from the item depicted in Figure 11.16.

of the analyst is to properly document clothing stains at the scene, so they are not subsequently destroyed. Additionally, the analyst must try to educate those coming in contact with suspects and subjects, teaching initial responders to be cognizant of bloodstains and to seize bloody clothing whenever practical.

A critical concern in clothing examinations is distinguishing contact stains from spatter. This evaluation simply requires the analyst to utilize 20 to 60× magnification and

Figure 11.21 A close-up photograph of Stain #5 from the item depicted in Figure 11.16. As this pattern is made up of several very small stains, additional macro-photographs are necessary.

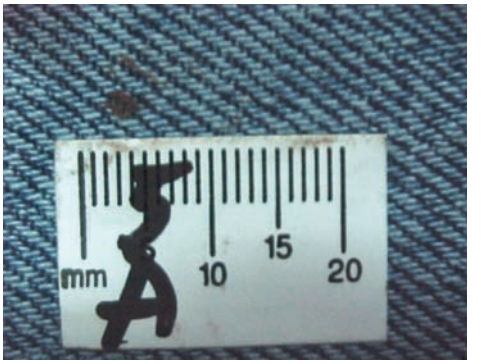


Figure 11.22 A close-up photograph of Stain #5A from Pattern 5 depicted in Figure 11.21. The larger orange label is too big for the macro-photograph, so an additional small millimeter scale is introduced alongside the stain and annotated so the viewer knows which stain they are looking at.

look for clear instances of the characteristics of each. The analyst will not be able to answer this issue in every single instance, but more often than not, this simple evaluation will resolve the issue.

Even basic considerations such as directionality and impact angle must be considered cautiously when dealing with cloth and fabric based upon the nature of the target surface. Various fabrics will all but eliminate the ability to distinguish this information. The analyst should always know the nature of the cloth or fabric being evaluated before defining any specific conclusions.

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2. Slemko, J., Bloodstains on Fabrics, *International Association of Bloodstain Pattern Analysts News*, December 2003, pp. 3–11.
3. White, B., Bloodstain Patterns on Fabric, *Canadian Society of Forensic Science Journal*, Volume 1, 1986, pp. 11–12.

Presumptive Testing and Enhancement of Blood

12

CHARLENE MARIE

Is this stain *blood?* It is not difficult to identify the red, slightly viscous material oozing from a wound or pooled around a body. But what about the brownish-green stain on the ax handle? Or the dark brown stains on the fence post? What about that sticky looking reddish brown material on the interior driver's door? The true nature of certain forms of blood and other stains found in the crime scene will be anything but evident to the analyst.

A major part of the identification of a stain as blood is based on context and observable physical properties. Simply put, when it is obvious the stain is the result of an injury, there is little issue with a call of "blood." Just the same, the presence of pinkish red cerebrospinal fluid or a dark red pool showing serum separation at the edges certainly indicates blood. Many times, however, the appearance of the blood has changed and/or the association of the stain with a victim or suspect is not necessarily evident. The first step in making a determination is to visually examine the stain. A good description and documentation of the target stain will often allow confident conclusions regarding the presence of blood on a target.

When the context and physical properties do not clearly indicate blood, presumptive tests are a viable and vital part of an analyst's toolkit. Even if the stains have the appearance of blood, they may still need to be tested.

The next step is selective presumptive testing of the stain. Presumptive testing of blood and bloodstains is an important part of evidence collection and scene analysis. What may be apparent at the scene may not be so clear in the courtroom, so good documentation and appropriate testing are important tasks in the analyst's scene work.

A presumptive reagent is a search tool. A positive presumptive reaction allows a conclusion that the material tested is most likely blood. It implies that the sample should be collected and that further testing should be done. A responsible field report would incorporate all the information available, including the presumptive result. The report might read, "Presumptive testing indicates (or corroborates) the presence of blood." Similarly, if a presumptive test does not indicate the presence of blood, it is proper to record that "blood was not detected." That does not mean blood is not present; it means that using the available methods and reagents, we did not find blood.

Presumptive Tests

There are several useful presumptive reagents. They each have their advantages and shortcomings. Some of the most sensitive and selective reagents have been abandoned because of their toxicity. The ideal reagent will offer good sensitivity and good specificity but not be toxic to the user. It will be easily prepared and easily used. The results will be unambiguous. Additionally, the reagent should have a good shelf life. There is no single ideal reagent, but there are several good reagents available that meet these standards.[1,2]

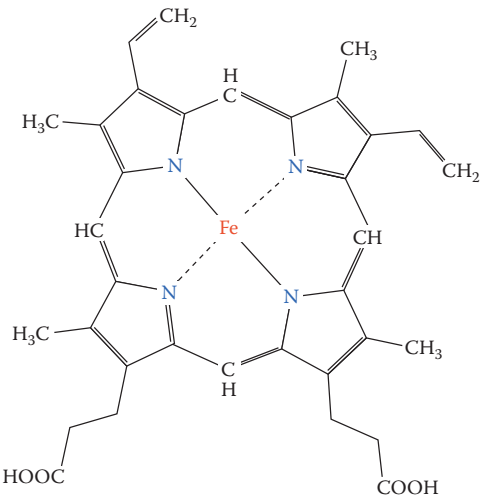

Figure 12.1 The heme structure. Phenolphthalein, o-tolidine, leucocrystal violet, 3,3′,5,5′-tetramethylbenzidine (Hemastix™), leucomalachite green, fluorescein, and luminol are commonly used as presumptive reagents. They react with the iron (Fe) present in the hemoglobin molecule.

Most of the presumptive reagents are colorless dyes that become colored in the presence of blood and oxidizer. All of the presumptive tests discussed here detect hemoglobin (Hb). It is this iron-containing heme portion of the hemoglobin molecule that is detected, regardless of the dye that is used. The heme catalyzes the reaction with a presumptive dye and peroxide.

Most mammalian forms of the hemoglobin molecule have four heme groups per hemoglobin molecule. Figure 12.1 shows the heme structure. The iron atom (Fe) in the middle of a porphyrin structure in the heme is responsible for oxygen binding, transport, and release. This is the most important function of the heme group.

Catalytic presumptive tests using chemical reagents are based on the principle of the presence of peroxidase-like activity of hemoglobin in blood. This peroxidase-like activity catalyzes the oxidation by peroxide of the various dyes and results in a rapid color change of the test reagent. Phenolphthalein, o-tolidine, leucocrystal violet, 3,3',5,5'-tetramethylbenzidine (used in Hemastix™), leucomalachite green, fluorescein, and luminol are commonly used presumptive reagents. These reagents react with some plant materials, cleaning agents, metals, metal salts, and other sources of iron. For this reason, these tests are *presumptive* for blood, not confirmatory.

While any one of these reagents can be used as a presumptive test for blood, before choosing a presumptive testing reagent it is important to consider the pros and cons of the various reagents.

Sensitivity, specificity, safety, and simplicity are the basic criteria for choosing a reagent. Once the presumptive tests are done, the target stain must still be viable for genetic testing as well. Additionally, substrate and environmental conditions may be important considerations. What works well in the laboratory may be cumbersome in the field. What shows up clearly on a light surface may not show up as well on a dark one. Fortunately, there are several good choices and it is prudent to be familiar with more than one.[3]

An important consideration, whenever organic dyes are used, is the possibility of carcinogenic/mutagenic consequences. While known carcinogens are avoided, gray areas

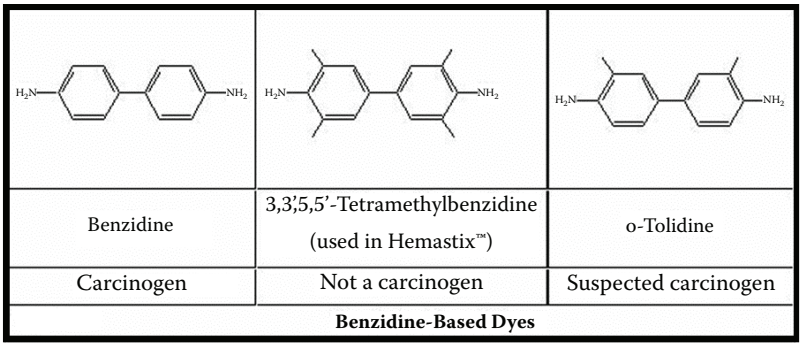

Figure 12.2 Benzidine and its derivatives. The derivative, o-tolidine (3,5-dimethylbenzidine), is a suspected carcinogen. It is still in use by some practitioners because of its excellent sensitivity.

exist for some of the presumptive tests regarding their inclusion as suspected carcinogens. One of the ways to evaluate a particular dye for mutagenic behavior is the Ames test.[4]

The Ames test is an assay that is done by introducing the material to be tested onto a specifically designed growth medium (usually doped with genetically modified salmonella). If the suspected material is able to grow colonies in the medium, it is considered a mutagen. The results are sometimes listed as "mutagenicity in salmonella." Since most carcinogens are also mutagens, if a material tests positive as a mutagen, the material is also considered a suspected carcinogen.

If a material is cleared via the Ames test, it means that the material is not mutagenic and is, therefore, *most likely* not carcinogenic. The Ames test is valuable because many materials that might not otherwise be tested can be screened in this method. A shortcoming of this screening test is that the material is tested against bacteria and then correlations are made regarding its effects on living beings.

Benzidines

Benzidine and its derivatives (see Figure 12.2) were used extensively as blood detection reagents because of their good sensitivity. However, benzidine has been identified as a human carcinogen and is no longer recommended for use. A related material that is very commonly used is Hemastix™. The active dye in Hemastix™ is 3,3',5,5'-tetramethylbenzidine (TMB).[5] This material, while structurally related to benzidine, has been tested via the Ames test and found not to be a mutagen. Additionally, the construction of Hemastix™ has the active materials embedded at the end of a plastic strip. The construction of this product contributes to the safety and the ease of its use for testing.

Triarylmethanes

Phenolphthalein (Kastle-Meyer reagent), leucomalachite green, leucocrystal violet, and fluorescein are all in the triarylmethane group (see Figure 12.3). Like the benzidine group, they share a common basic structure. Structural variations give rise to their different color reactions and, in the case of fluorescein, cause the reaction to fluoresce.

Phenolphthalein was used for almost a century in commercial laxative formulations.[6] In 1997, the FDA concluded that phenolphthalein potentially *could* cause cancer in humans.

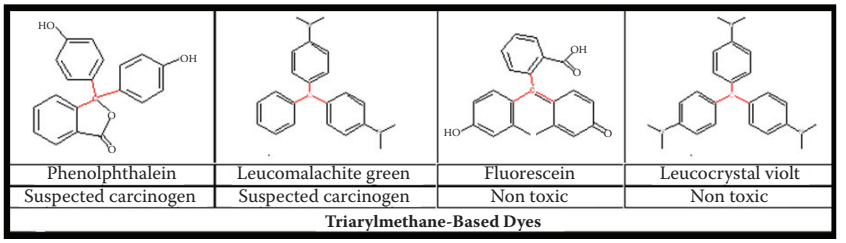

Figure 12.3 Triarylmethane is the "backbone" or common structure of phenolphtalein leucomalachite green, fluorescein and leucocrystal violet.

The Ames test for phenolphthalein did not detect it as a mutagen, but studies using mice did show evidence of carcinogenicity.

While fluorescein and leucocrystal violet are referred to in the literature as nontoxic, leucomalachite green is listed as a *suspected* carcinogen. Small changes in structure may yield surprising changes in toxicity. It is a good rule to be suspicious and, therefore, careful of *any* chemical testing reagent.

Luminol

Luminol is a chemiluminescent molecule. Chemiluminescence is the emission of light during a chemical reaction. Luminol (5-amino-2,3-dihydro-1,4-phthalazine-dione) produces light when it reacts in the presence of hemoglobin (see Figure 12.4). The molecule in the excited state (in Figure 12.4) emits lights and then returns to a ground state. This is a fast reaction and because nitrogen (n^2) was expelled, it is not reversible. More luminol must be

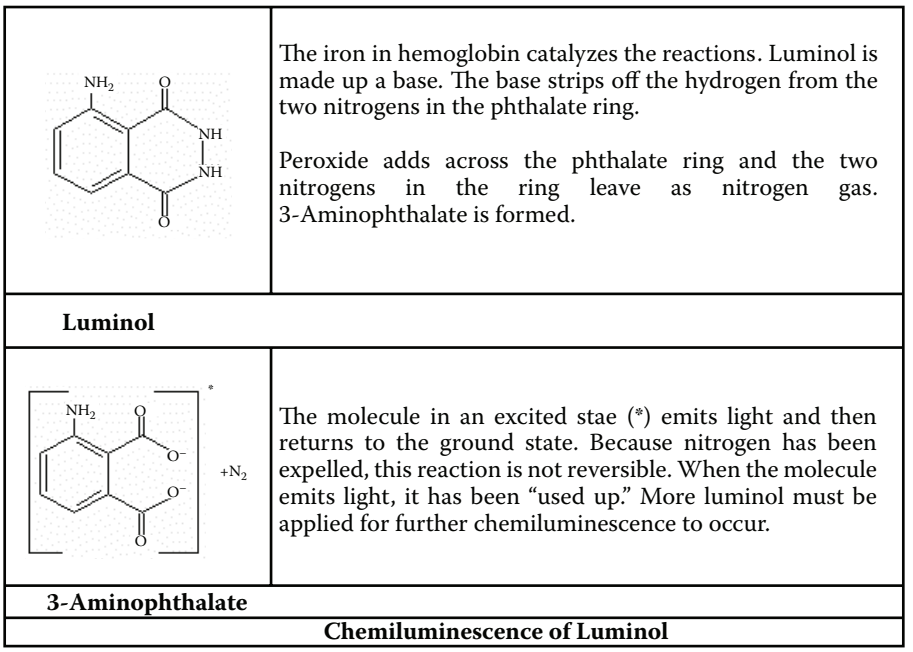

Figure 12.4 Luminol (5-amino-2,3-dihydro-1,4-phthalazine-dione) produces light (chemiluminescence) when it reacts in the presence of hemoglobin.

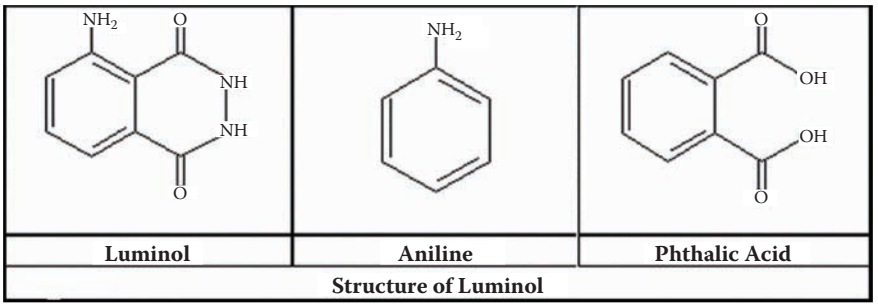

Figure 12.5 The structure of luminal is similar to that of aniline and the phthalates.

added for further chemiluminscence to occur. The structure of luminol is based on aniline and the phthalates (see Figure 12.5). There was some evidence that exposure to aniline by dye workers resulted in an increase in liver and bladder tumors. This gave obvious rise to concerns that luminol might be a suspected carcinogen. Subsequent research has shown this is not the case.[7]

Choosing a Reagent

Dye choices for presumptive blood testing include the benzidines, the triarylmethanes, and the chemiluminescent molecule, Luminol. It is common practice to choose phenolphthalein, leucomalachite green, or 3,3′,5,5′-tetramethylbenzidine (Hemastix™) when the stains are patent, or visible. Luminol, leucocrystal violet, and fluorescein are generally used for testing for the presence of latent blood or to enhance latent patterns. Note that it is the *non-toxic* reagents that are generally used to search for latent blood. Part of the reason is their excellent sensitivity, but it is also important to note that searching for latent blood often involves spraying a chemical reagent. It is much safer to spray a known non-toxic material.

Whichever testing reagents are used, it is important to validate the sensitivity and specificity of the reagents and to verify that the reagents are working properly before they are used in evidential testing. Several commercially available products may be used. It is still important to test these materials yourself before committing them to evidential testing.

A good understanding of the sensitivity, specificity, repeatability, and range of responses of the reagents on a variety of target substrates is important. The analyst should recognize the various sources of interference (false positives) (see Figure 12.6). Keep in mind that not all surfaces are created equal. An excellent example is black denim, which is a far more difficult surface to test than, say, white cotton. It is also important to develop familiarity with the range of responses that might be seen. The analyst must understand how the reagent of choice will behave on a variety of substrates and under varying environmental conditions.

It is always a good practice to check the reagent each day that it is used by testing a known blood sample and checking a reagent blank. The analyst may also want to check the reagent on bloodstains of varying strength, especially if they are considering testing materials in the field and are unsure of how old they are or how concentrated the stains are.

One method for setting up a dilution series is to serially dilute whole blood with distilled water and then apply samples of the dilutions to cardstock (see Figure 12.7). The card-

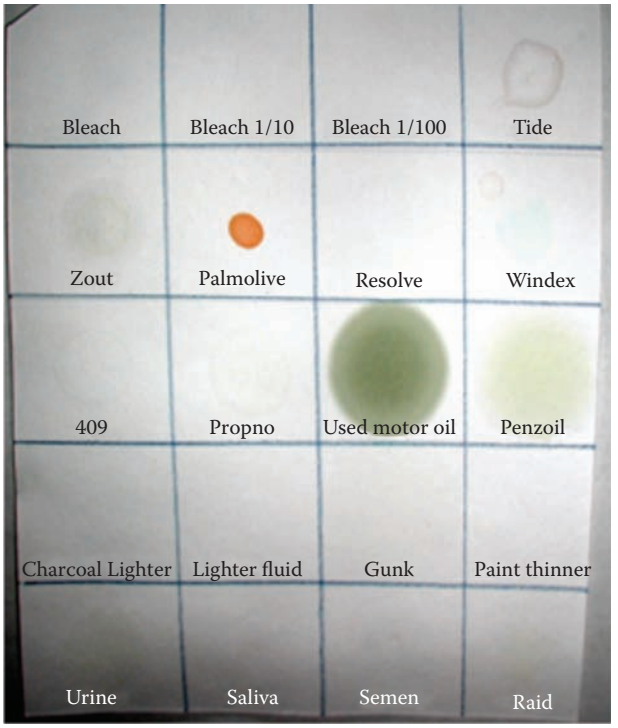

Figure 12.6 A stock card used to test for interference. The card includes samples of common cleaners, soaps, lighter fluid, motor oil, and other materials. Each substance is placed in a separate test grid to check for reactivity with the presumptive test. The cards can be prepared in advance and stored for future use.

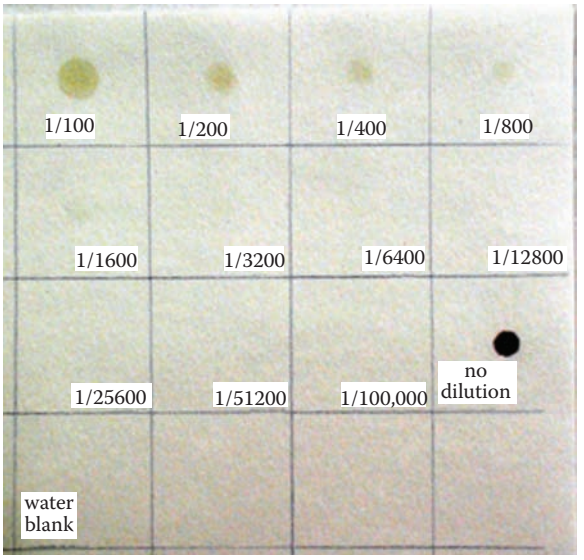

Figure 12.7 A dilution series test card. The cards are used to test the chemical's sensitivity to diluted stains. They are generally prepared in advance and stored in a refrigerator. They can be used when necessary to test the chemical's response.

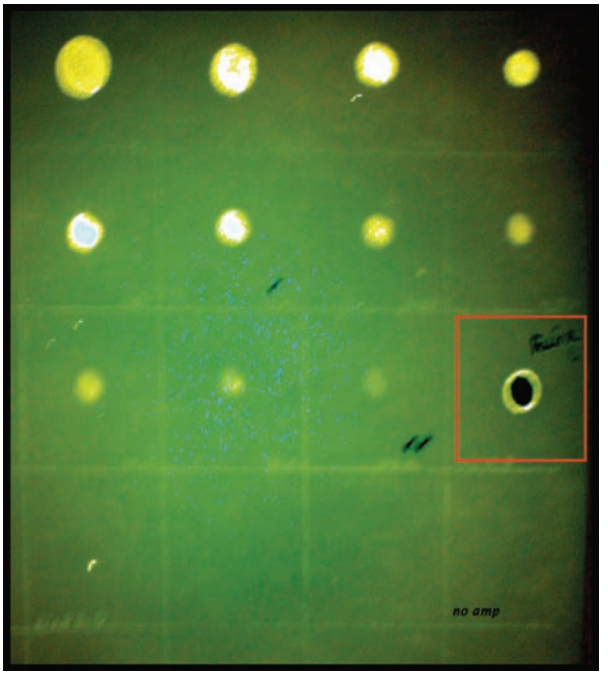

Figure 12.8 An example of a fluorescin reagent response using a bloodstain dilution card. 20 µl aliquots of blood dilutions were applied to the white cardstock grid. The box highlights an undiluted stain (whole blood). Note that the stain reacts only around the boundary, which is a typical response of fluorescin when sprayed on whole blood.

stock is divided into grids and each square labeled with the dilution to be applied. Several of these may be prepared, air-dried, and stored frozen until needed. This approach works well for reagents that will be sprayed onto a target. This is a fast way to perform a quality control (QC) check *and* test the sensitivity of the reagent in a field setting.

When you conduct dilution or interference tests, it is a good idea to maintain a record of the results for both. These results become a guide of how your reagent behaves in your hands. It is also very helpful to have a written track record of the reagent's performance. It is easy to photograph the test, both before and after treating the stains, to document the effort.

As noted above, a QC check of the reagent should be done each day the reagent is used. The reagent should be tested using a known blood source and a blank. The blank should include any solvent used to prepare the reagent. The QC check can be included in lab or field notes. A sensitivity check may be incorporated into the QC check by using the bloodstain dilutions card, as shown in Figure 12.8.

Just because a dilution series reacts down to 1 in 100,000 or better on a piece of white cardstock or other test medium does not mean those results will always occur in a field application. Each of the presumptive searching reagents reacts differently on different substrates. As mentioned, black denim is a difficult substrate and you will have a much more difficult time finding very tiny and/or very dilute stains on such a surface. It is extremely important that you use your eyes first. Examine each item, using different lighting arrangements and magnification, before applying any chemical reagent.

Genetic Testing Considerations

While there is still some controversy about the effect of presumptive testing on DNA sampling, the dyes used and the formulas given in this chapter are all safe to use separately or in tandem and still allow genetic material to be recovered for DNA testing using Polymerase Chain Reaction (PCR).[8,9] The real challenge for presumptive testing and DNA sampling arises for already compromised samples. Tiny specks of apparent blood or faint smears that might be blood are, of course, the samples that must be handled with the most care. These samples are the most susceptible to both contamination and destruction. As it turns out, they are also often the most important samples.

Handling alone can cause the genetic material to diminish simply due to the mechanics of manipulating the material.[10] It is possible to deluge a tiny stain with a chemical reagent, making it impossible to find the sample later in order to do further testing. Dilution, mechanical damage, and contamination are *always* possibilities and they are always a significant consideration when dealing with already compromised samples.

Contamination of the sample may or may not be something that is known or recognized. Contamination that is known can always be accounted for in the context of the scene (e.g., a suspect bleeding on a victim, an examiner sneezing on a sample, the wind knocking a sample into another sample). Care must be taken to prevent or limit sources of contamination as much as possible, to be observant for possible sources of contamination, and to make note of any sources of contamination that are discovered.[11]

Most of the evidence we encounter is mixed with something from the environment. Often the evidence has dirt, fibers, foodstuff, or some other environmental association. Most of these contaminants will not further complicate genetic testing, but they can make the cleanup of the sample by the DNA analyst more difficult. It is always important to describe the evidence context so that if information about environmental context will contribute to the genetic analysis, the DNA analyst can make sense of it. For example, bloodstains from the victim that are on the suspect's clothes will most likely yield a major donor profile from the victim *and* a minor donor profile from the suspect. The location of the bloodstain on the suspect's clothes is always a compelling association. These considerations make it even more important to secure reference samples whenever possible from all victims and suspects in order to assist in untangling any combined DNA profiles.

The analyst collecting the sample must not add anything further to the sample. Proper evidence handling, such as wearing protective gloves and clothing, using disposable or cleanable tools, and securing the samples properly will help ensure the samples arrive at the laboratory for testing without altering their original condition.

Formulations*

Hemastix™, o-tolidine, phenolphthalein, and leucomalachite green are the reagents most commonly used for the detection of patent blood. Formulas for their preparation, testing procedures, and interpretation of the results follow.

* It should be noted that various formulations exist for the chemicals that will be discussed. The formulations presented here are currently in use and found in the California Department of Justice Biology Methods Manual.

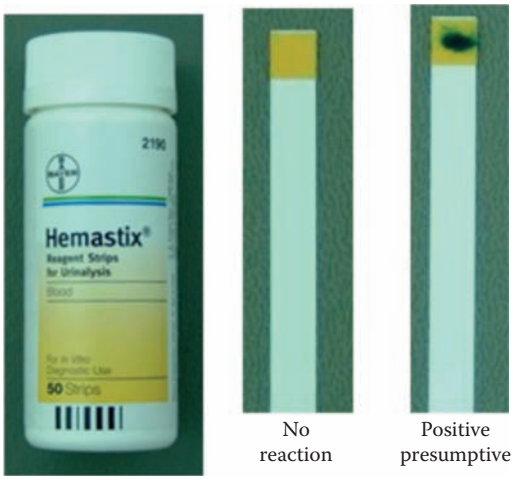

Figure 12.9 Hemastix™ are a commercially prepared presumptive test based on tetramethylbenzidine (TMB). A positive presumptive result is a blue-green discoloration on the test pad. The analyst should always ensure the package has not exceeded the expiration date. (Photograph courtesy of Sara Larsen, California Department of Justice, Redding Laboratory, Redding, CA.)

Hemastix™

Hemastix™ are plastic strips to which is affixed a reagent pad which is used for testing stains or liquids for the presence of blood.[12] The dye and peroxide are both on the test pad. This makes use of Hemastix™ a one-step test. The oxidizer is diisopropylbenzene dihydroperoxide; and the dye is 3,3'-5,5'tetramethylbenzidine (TMB). The reagent pad is moistened and the embedded dye and peroxide react to heme to produce a dark green/blue-green color (see Figure 12.9). This reagent strip is ready to use upon removal from the bottle and the strip is disposable.

Hemastix™ Procedure

- This is a one-step chemical test. When the reagent pad is moistened with a small amount of water, it contains all the necessary chemicals to perform the test.
- To demonstrate that they are working appropriately, a known dilution of human bloodstain (positive control) and reagent blank (negative control) must be tested each day the reagent strips are used.
- To conduct an indirect test, rub a moistened swab or a piece of small folded filter paper on a suspected stain and then touch the swab or filter paper to the moistened reagent pad.
- To conduct a direct test, cut or swab a very small portion of the suspected stain and touch it to the moistened reagent pad. Alternatively, apply a small aliquot of stain extract directly to the pad.
- If available, test a small, unstained portion of the substrate material.
- A positive presumptive result for blood is rapid color change to dark green/blue-green. No immediate color change is a negative result.
- As with other reagents, exposure of the reagent over time will result in a slow color change. This is not a positive result.

Preparing Phenolphthalein, Leucomalachite Green, and o-Tolidine

The three dyes phenolphthalein, leucomalachite green, and o-tolidine are used in a two-step procedure. First, the reduced dye is applied, followed by the oxidant. The most common oxidant is a 3% solution of hydrogen peroxide (H_2O_2). This can be purchased or prepared from a stronger solution by diluting it in distilled water.

To prepare the dyes, phenolphthalein is heated in a basic (sodium hydroxide) water solution, and leucomalachite green is heated in an acidic (acetic acid) water solution. Zinc is added to both to catalyze the reduction. Be careful when disposing of used zinc because as zinc dries, it generates heat and can start a fire. The other caution when heating these solutions is that hydrogen gas is formed. Take care not to seal the solutions too tightly. The hydrogen gas needs to vent.

Phenolphthalein Solution

Phenolphthalein is colorless in a basic solution. To make the testing reagent, phenolphthalein is heated in water to which sodium hydroxide has been added.

2 g phenolphthalein
20 g sodium hydroxide pellets
100 ml distilled water
20 g zinc

Boil gently (or reflux) on a heat block under a hood until the solution is colorless. Store the solution refrigerated in a dark bottle with an additional amount of zinc to keep the solution in reduced form.

Once the stock solution is prepared, a working phenolphthalein solution is created from it. Prepare a 1:5 dilution of the stock solution with ethanol (e.g., 2 ml stock + 8 ml of reagent ethanol). Add zinc to keep the working solution colorless (reduced).

As previously described, phenolphthalein and peroxide react with the hemoglobin in blood. The hemoglobin catalyses the reaction and phenolpthalein donates two hydrogens. In the Kastle-Meyer test, phenolphthalein loses two hydrogen atoms. Phenolphthalein in basic solution is colorless, but the phenolphthalein ion formed by the removal of these two hydrogen atoms is pink, which is what affects the color change in this test (see Figure 12.10).

Leucomalachite Green Solution

To produce the solution, leucomalachite green is heated in an acidic solution until it is colorless. Malachite green is the oxidized form. Leucomalachite green is the reduced form.

0.5 g leucomalachite green
50 mL glacial acetic acid
75 mL distilled water
2.5 g zinc

Boil gently (or reflux) on a heat block in a hood until solution is colorless. Store the solution refrigerated in a dark bottle with an additional amount of zinc to keep the solution in reduced form.

Figure 12.10 A positive phenolpthalein reaction. The swab is moistened with alcohol and then rubbed against the suspected stain. A drop of phenolpthalein solution is placed on the swab, followed by a drop of peroxide. The pink color should develop immediately.

o-Tolidine Solution

To produce the solution, o-tolidine needs to be mixed in acidic ethanol; it requires no heating or zinc. However, o-tolidine is a benzidine derivative and it is a suspected carcinogen. Handle this reagent with care and use appropriate precautions. Do not spray this reagent. Always wear nitrile gloves and handle and mix the o-tolidine solution beneath a hood.

0.5 g o-tolidine
50 ml ethanol
50 ml glacial acetic acid

Mix the above materials in a flask and transfer to a dark reagent bottle. Store refrigerated.

Testing Procedure Using Phenolphthalein, Leucomalachite Green, and the o-Tolidine Solutions

- These are two-step chemical tests. A known human bloodstain (positive control) and reagent blank (negative control) should be tested each day the presumptive test reagents are used in order to demonstrate that they are working appropriately.
- For an indirect test, rub a moistened swab or a piece of small folded filter paper on a suspected stain. For a direct test, cut a very small portion of the suspected stain.
- If available, test a small, unstained portion of the substrate material.
- Add a drop of the working solution to the swab, filter paper, or cutting. Add a drop of 3% H_2O_2.
- The appearance of a rapidly developing pink (phenolphthalein) or blue-green (leucomalachite green and o-tolidine) color at this stage is a presumptive positive result for the presence of blood. A color change before the addition of the peroxide may indicate the presence of a chemical oxidant.
- No immediate color change is a negative result.

Interpretation

In order to obtain a reliable interpretation it is important to consider the following information:

- Catalytic tests are very sensitive, but not specific.
- The appearance of a rapidly developing pink (phenolphthalein) or blue-green (leucomalachite green and o-tolidine) color is a positive presumptive test for the presence of blood. A color change before the addition of the peroxide may indicate the presence of a chemical oxidant.
- For Hemastix™, the appearance of a rapidly developing dark green/blue-green color on the reagent pad is a presumptive positive result for the presence of blood.
- The positive color reaction alone should not be interpreted as positive proof of blood. An appropriate conclusion is: "Stain A was chemically tested for blood. The presumptive test for blood was positive."
- If visual characteristics and presumptive chemical tests are positive, then the results may be reported as: "The sample is apparent blood."
- The major sources of "false-positive" reactions are chemical oxidants and vegetable peroxidases.
- Fresh vegetable peroxidases can give reactions similar to blood, but the reactions are usually slower and weaker. Vegetable peroxidase activity fades rapidly upon drying. In addition, vegetable stains generally can be distinguished visually from blood.
- Color development before the addition of H_2O_2 may be due to the presence of a chemical oxidant. Copper and nickel salts are common chemicals responsible for false-positive reactions.
- If the chemical results are negative, the results may be reported as: "No blood was detected on the sample."

Searching for and Enhancing Latent Blood

When the presence of latent blood is suspected, three blood presumptive search and enhancement reagents are available: luminol, fluorescin, and leucocrystal violet (LCV). All three reagents are very sensitive, and each has advantages and disadvantages. It is possible to use them sequentially if needed.

Luminol is a chemiluminescent reagent that produces a light-blue glow when it comes into contact with blood.[13,14] See Figure 12.11. Luminol is easy to mix and use. The luminol glow is very characteristic, but it does not last very long and requires a darkened environment to visualize properly. There are various commercial luminol products available. These include Hemaglow™ and Bluestar™.

Crystal violet is a dye that is used as a general protein stain. General protein stains are less specific than presumptive blood testing reagents. However, the *reduced form,* LCV, is a presumptive blood reagent.[15] The colorless LCV turns purple on contact with latent blood. It can be used in available light and is very effective on light-colored surfaces.

Fluorescein must also be reduced to the colorless fluorscin before using.[16,17] The reduced form is sprayed on a substrate and is then oversprayed with dilute hydrogen peroxide. When in contact with latent blood it produces a bright yellow-green color when visualized with an alternate light source (ALS). The fluorescence is very bright and lasts well. It does

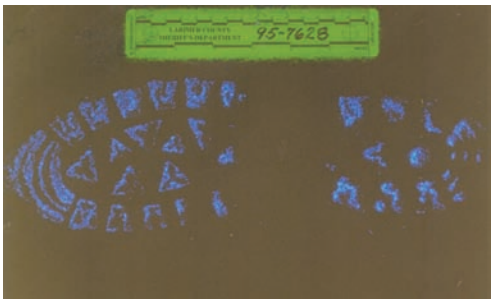

Figure 12.11 A footwear pattern transfer enhanced by luminol. In this method, luminescent tape was applied to the back of a clear plastic ruler. Following application of luminol to the scene, the ruler was inserted giving a visible scale of reference. (Photograph courtesy of T. Daniel Gilliam, Larimer County Sheriff's Department, Fort Collins, CO.)

require the hydrogen peroxide overspray and the use of an ALS. Luminol and LCV require no overspray or light source to visualize the result.

Fluorescin and LCV are triarylmethanes. They are structurally close to phenolphthalein and leucomalachite green, and they are thought to react with blood in a similar fashion.

These processes, as described, will not degrade DNA that may be present in a substrate. Any processing, however, may reduce the amount of DNA present due to the manipulation of the material.

Just as with reagents used to test patent blood, these three latent blood-testing reagents are subject to the same false-positive results in the presence of metal salts. Additionally, reactions are seen on dilute hypochlorite stains, although the color, intensity, and duration are different from the results seen on latent bloodstains.

Leucocrystal Violet (LCV) Preparation

As previously described, the basic structure of LCV (see Figure 12.12) is the triarylmethane skeleton. To prepare the LCV solution:

- Dissolve 10 g of 5-sulphosalicylic acid in 500 ml of 3% H_2O_2.
- Add 4.4 g of sodium acetate.
- Add 1.1 g of LCV.

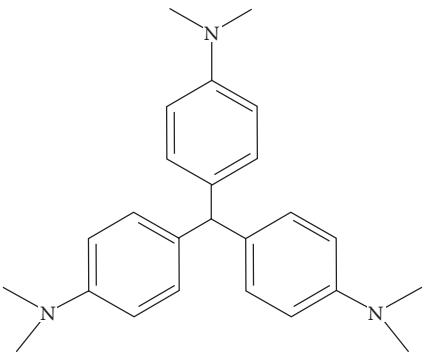

Figure 12.12 The structure of leucocrystal violet (LCV) is based on the triarylmethanes.

Alternate LCV Reagent Preparation Method

The reagent may also be prepared in the field by using a purchased 473-ml bottle of 3% H_2O_2. In this method, the solution is produced as follows:

- Pour a small volume of the H_2O_2 into a small cup and add 10 g of 5-sulphosalicyclic acid.
- Dissolve 1.1 g of LCV into the above solution.
- Pour this solution back into the bottle, replace the cap, and shake for 30 s.
- Pour some of the solution from the bottle back into the small cup and add 4.4 g of sodium acetate. Mix until dissolved and pour back into the bottle.
- Replace the cap and mix thoroughly.

Note: 5-sulphosalicylic acid helps to fix blood to the substrate on which it is present. Discard LCV crystals if they become yellow.

Fluorescin Spraying Solution Preparation

The materials and reagents used to prepare fluorescin include:

Fluorescein (e.g., Aldrich F245-6)
Zinc, granular
Ethanol
Glacial acetic acid
Hydrogen peroxide (H_2O_2)
Sodium hydroxide (NaOH)
Distilled water

Fluorescin can be prepared either by an acidic reduction in alcohol or by a basic reduction in water. The alcohol preparation is useful for vertical and/or slick surfaces. Both preparations are oversprayed with H_2O_2 diluted to 3% in either ethanol or distilled water.

Fluorescin in Alcohol Preparation

To prepare the alcohol fluorescin solution:

- Dissolve 0.1 g of fluorescein in 20 ml of ethanol in a small, lidded container.
- Add 2 g of granular zinc.
- Then add 1 ml of glacial acetic acid.
- Warm for about 30 min. (You can use the warmth of your hand around the container.)
- Decant or pipette 1 ml of the stock solution into 99 ml of ethanol to prepare the spraying solution.

Note that the analyst can vary the dilution of the stock solution to adjust to any sensitivity issues encountered on scene.

Fluorescin in Water Preparation

To prepare the water-based fluorescin solution:

- Add 0.1 g of fluorescein to 20 ml of distilled water in a small, lidded container.
- Add 2 g of granular zinc.
- Then add 1.0 g of sodium hydroxide (NaOH) pellets.
- Warm for about 30 min.
- Decant or pipette 1 ml of the stock solution into 99 ml of distilled water to prepare the spraying solution. Once again, dilution of the stock solution can be varied to increase or decrease sensitivity.

The alkaline fluorescin preparation just described results in a clear, but slightly lime-green colored solution (see Figure 12.13). This is diluted to produce a working solution and is then sprayed onto the target. In the presence of heme, this solution is oxidized and will fluoresce in a lime-green color. This fluorescence is visualized with an ALS. Generally, the technique works best when operating the ALS at the 445 to 455 nm range with a yellow barrier filter, but can also be visualized at 485 nm with an orange barrier filter (see Figure 12.14).

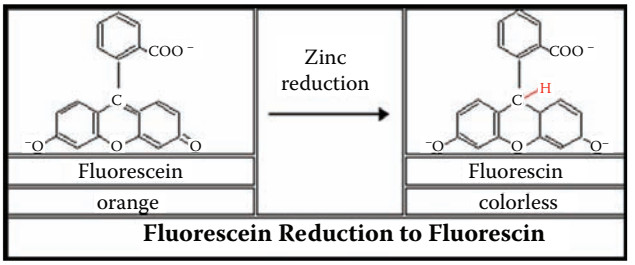

Figure 12.13 Fluorescin is prepared in either an acidic reduction in alcohol or by a basic reduction in water. The alcohol preparation is useful for vertical or slick surfaces.

Figure 12.14 A fluorescin reaction on carpet. To visualize the fluorescence the analyst utilizes an alternate light source (between 445 and 485 nm) and either a yellow or orange barrier filter.

Before applying fluorescin, the substrate in question is always checked with the ALS to identify any natural fluorescence or other contaminants that may fluoresce. Any contaminated areas are marked to ensure that they are not mistaken as part of the reaction.

Luminol

The materials and reagents used in luminol include:

Luminol (3-Aminophthalhydrazide)
5% sodium hydroxide (NaOH)
3% hydrogen peroxide (H_2O_2)
Distilled water

Reagent Preparation

To prepare the luminol solution:

- Add 2 ml 3% H_2O_2 to approximately 50 ml distilled water.
- Mix 0.05 g luminol into 10 ml of 5% NaOH.
- Add this to the water/peroxide solution.
- Bring the final volume up to 100 ml with distilled water.

Alternate Reagent Preparation

In this preparation, the oxidizer perborate is used in place of peroxide. Sodium perborate is a solid material; thus, kits can be prepared ahead of time and the materials mixed in the field.

0.5 g luminol
3.5 g sodium perborate
25 g sodium carbonate
250 ml distilled water
250 ml distilled water

- Dissolve luminol and sodium carbonate in distilled water.
- Dissolve sodium perborate in 250 ml distilled water.
- Combine and spray.

Safety Considerations

While no safety data exist that incriminates these dyes as a health hazard to humans, normal precautions should be followed. Spraying should be done, if possible, in a well-ventilated area and with suitable protection (lab coat or other protective clothing, gloves, mask, etc.). Respiratory protection is recommended when working in an enclosed space.

Hydrogen peroxide is very irritating to eyes, skin, and the respiratory system. Hydrogen peroxide is an oxidizer, which may make organic substances more flammable on contact.

Alcohol does pose a possible flammable risk and appropriate ventilation is necessary. Open sources of flame, such as pilot lights, must be checked and eliminated before spraying. Keep in mind that any evidence that was chemically treated should be marked in a manner that anyone coming in contact with it later will be aware of the nature of the treatment.

Procedure for Using Luminol, LCV, and Fluorescin

- Reagents should be checked each time before they are used. At a minimum, a known blood sample should be checked. Keep in mind that undiluted blood may quench the reaction, although the borders of the stain will glow. (Refer to Figure 12.8.)
- These reagents are most useful when prepared shortly before spraying and should be disposed of when the application is complete.
- Ensure that appropriate documentation and photographs have been taken prior to any chemical enhancement procedure.
- If fluorescin is being used, areas that glow with an ALS should be checked and marked before spraying.
- Spray the reagent lightly with as fine a mist as possible. A Chromist™ sprayer or similar may be used on smaller areas. Plastic garden-type sprayers are useful for larger areas. Very large areas should be sprayed in sections. Areas may be re-sprayed as needed.
- Photograph or otherwise document areas where reactions are observed.

As indicated, luminol reacts to many things, but through trial and use the analyst can often identify such false-positive reactions. The luminol reaction in particular should be evaluated using three criteria: color, intensity, and duration. The color reaction should be a bluish-white to blue-green. White-blue and darker violets occur in any number of false positives. The intensity of the reaction should build over a very short period and it should remain evident for some period, although it will fade. Immediate flashes of white or white-blue are indicative of bleach and cleaning products. Due to past abuses, some courts now prohibit testimony regarding its use and any conclusions drawn from it. The best advice is to try to confirm the presence of blood, which unfortunately given the trace amounts involved, is difficult.

Protein Stains

There are additional enhancement dyes available that react with various proteins in body fluids and blood. The most common in use at crime scenes is amido black. The resulting enhancement is a black to black-blue color. Amido black can be applied both as a water-based or methanol-based application. Water-based procedures, which are most applicable for use at the crime scene, require some level of effort and should not be undertaken without prior experience (see Figure 12.15). Protein stains are not considered presumptive for blood, and any conclusions reached should be carefully considered in the context of the crime scene.

Figure 12.15 An amido black reaction on fabric.

Photo-Documentation

Another concern for the analyst is documenting the luminol reaction. In the late 1980s, Gary Reni and Fred Gimeno perfected methods of photographing luminol reactions. Prior to their efforts, generally all luminol photographs were exposed in completely darkened rooms. The result was good luminescence but no frame of reference for the viewer. One simply could not tell where the reaction occurred on the evidence or in the scene. By using paint-with-flash techniques similar to those used in spelunking and outdoor crime scene photography, Reni and Gimeno produced images that included both the luminescence and the evidence item. Their efforts are documented in two articles published in the *Journal of Forensic Identification*.[18,19]

Ray Clark of the Oklahoma City Police Department uses similar time exposure techniques and a flashlight as a light source to effectively document luminol reactions. Clark usually starts with a 5-min time exposure, but may expose the negatives for as long as 15 min depending upon the strength of the reaction. At the end of the exposure, Clark uses the paint-with-light technique to add detail of the surrounding scene. This is done with a standard flashlight. The beam is turned on momentarily and reflected off various walls and surfaces surrounding the area in question. Figure 12.16 and Figure 12.17 are examples of luminol photography using this technique.

Fluorescin photography is much simpler, as an ALS is utilized. The ALS offers sufficient ambient light to demonstrate the background as well as the fluorescence. The only requirement is an appropriate barrier filter for the camera. As previously described, the filter may be either yellow or orange based on the wavelength of light utilized by the analyst.

Both luminol and fluorescin enhancements are best documented using a tripod. It may also be helpful to re-spray the target area. The luminol chemiluminescence intensity fades relatively quickly in relation to the time required to take a photograph. The fluorescin reaction will remain much longer.

With the advent of digital cameras, the task of photographing these reactions is much simpler. The analyst can test various exposures on scene and immediately adjust the camera based on the result. One simple method is to set the zoom and focus of the camera with the lights on. With the camera affixed to a tripod, photograph the target using available light. Then with the flash off and using the same camera settings (with tripod), open the shutter for as long as needed.

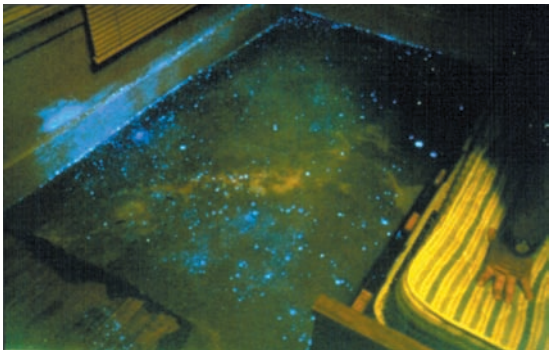

Figure 12.16 A suspected crime scene in which there was evidence of bloodshed, but also indications that the subject cleaned up the area. This photograph shows the scene following the application of luminol. The blue-green luminescence shows various stains including wipes, swipes, smears, a drag mark, blood trails, and spatter. (Photograph courtesy of Ray Clark, Oklahoma City Police Department, Oklahoma City, OK.)

Figure 12.17 The back stairs of the same crime scene from Figure 12.16. The drag mark was not evident in any fashion prior to the application of luminol. These photographs were taken in the dark, while a flashlight beam was bounced off the surrounding surfaces for several seconds. As a result, the photograph shows good luminescence and scene detail. (Photograph courtesy of Ray Clark, Oklahoma City Police Department, Oklahoma City, OK.)

Interpretation

- Luminol, LCV, and fluorescin are presumptive tests for blood. These reagents are much more sensitive than patent blood presumptive reagents. They are useful in the detection of patterns of older or indistinct bloodstains and in detecting the residue of blood remaining after a stain has been cleaned. It is important to visually examine surfaces before spraying.

- These presumptive searching reagents are subject to false positives similar to phenolphthalein and leucomalachite green.
- A positive reaction is presumptive for blood. Because these reagents are so sensitive, a positive reaction may be reported as: "The target area glowed. Therefore, this may indicate the presence of blood. Further testing may be indicated. No inference as to species of origin may be made."
- If no reaction is observed, the following may be reported: "No blood was detected."
- If good contrast between the substrate background and target is not observed, then no conclusion may be made. An example for wording in the report is: "The results were inconclusive."
- If the reaction is not similar to the control reaction (e.g., color, duration, intensity), then the result may be considered inconclusive and may be so reported.

Confirmation of Blood

Running more than one presumptive test (e.g., serial test using Hemastix™, followed by leucomalachite green) does not render a confirmation of blood. Presumptive tests are all presumptive. In response to the need to clarify the nature of the stain at the crime scene, various tests are now available that give a stronger indication as to the nature of the stain.

Immunoassay Confirmation of Blood

Immunoassay tests are designed to make use of the binding between an antigen and its homologous antibody. Commercially available tests include Hexagon OBTI™ and Hematrace™. Both tests were designed to screen for the presence of human hemoglobin utilizing an immunoassay technique. Because reactions have been observed with blood from species other than human and higher primates (specifically ferrets), this test is used to confirm the presence of blood, but in and of itself is not a true confirmation of human blood. Additional testing by the crime laboratory (e.g., a species test) may be used to confirm that the blood, once identified, is of human origin.

Immunoassay test cards should be checked before using them on evidence samples. A small amount of sample is extracted in the buffer solution provided. The amount of time for the extraction varies depending on how old the stains are estimated to be. Typical extraction times vary from 1 to 5 min. Older stains would require a longer extraction time.

A few drops of the extract is pipetted into a sample well marked "S" on the immunoassay card (see Figure 12.18). A colored band will appear in the control (C) section to demonstrate the card is functioning properly, and a similar band will appear in the test section (T), if blood is present. The card may be read up to 10 min after testing. Bands appearing after 10 min should not be considered a positive result. If the control band fails to develop, the test should be run again using a new card.

Summary

The various chemical reagents discussed offer the analyst tools to check presumptively for the presence of blood and to enhance latent blood patterns. The critical concern for analysts is

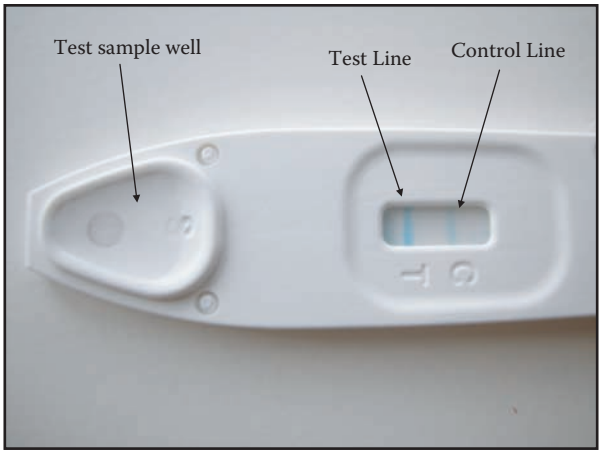

Figure 12.18 Immunoassay tests are also available to the analyst. Although not truly "human specific," these tests are more specific than other presumptive test techniques. After sampling the stain, a small amount of the test solution is placed in the sample well. A blue line will appear at the test (T) line if the test is positive. If a blue fails to appear at the control (C) line, the test should be repeated.

to be comfortable and practiced in the application and use of whatever reagent they choose. They must understand its capabilities and limitations.

The Author

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Documenting Bloodstains

13

There was a saying used in the Army CID regarding documentation: "If it's not written down, it didn't happen." Analysis and reconstruction demand this type of thinking whenever possible. No matter how good the evaluation and subsequent reconstruction, without documentation that allows us to share those efforts the evaluation may be for naught.

The Function of Documentation

Documentation serves several functions. These include:

- Verification of scene integrity
- Providing a quality court presentation
- Allowing outside analysis
- Providing for independent defense evaluation

The most important function of documentation is simply maintaining a record of the scene integrity as the analyst finds it. We want to be able to state with some authority the condition in which we found the evidence and how that evidence relates to other items. The court expects and demands this of the crime scene technician.

Good scene documentation precludes investigators from including post-incident artifacts in the analysis. It ensures the inclusion of evidence that may not survive the processing attempts and provides sterling proof to the court of the scene condition. To this end, documentation cannot be haphazard.

Understanding the issues for maintaining scene and evidence integrity in bloodstain pattern analysis demands an understanding of crime scene processing as a whole. This requires the analyst understand the six basic elements of crime scene processing which include: (1) assessing, (2) observing, (3) documenting, (4) searching, (5) collecting, and (6) analyzing. This book is not an appropriate vehicle for teaching all-encompassing crime scene processing techniques. For that reason, we offer this one comment: if the reader has not been exposed to training and experience in proper crime scene processing, that deficiency should be corrected before attempting to conduct a bloodstain pattern analysis or crime scene reconstruction. A resource for this purpose is *Practical Crime Scene Processing and Investigation* by Ross Gardner.

Eventually the court will need to know what the analyst knows. For court presentations, good documentation allows the analyst to clearly present the sometimes complicated information in a fashion that is understandable to the audience. This is particularly critical when considering presentations to the jury. In order to believe the reconstruction, the jury must understand the reasoning and evidence that support it.

Outside analysis is not that uncommon either. If a given department has no specific training in bloodstain pattern analysis or crime scene reconstruction, outside assistance

may be brought in. The outside analyst is limited by the documentation efforts of those who process the scene. Good documentation makes the outside analyst's job easier.

The final function of documentation, that of supporting defense evaluations, is also important. No matter what others may say, police agencies serve but one master — the truth! Therefore, the analyst should have little concern over defense analysis of his work. If we expect others to discover the same truths we found, they must certainly have access to the same information we had. If the analysts applied themselves appropriately, then any analysis or reconstruction will stand the test of scrutiny.

Granted, with regard to defense evaluations it is easily argued that little in the legal profession deals with truth. Defense attorneys or prosecutors will raise odd and curious questions; certainly they will not limit themselves to attacking only the evidence. Nevertheless, such attempts to muddy the water will be less successful if good documentation exists. Ours is an adversarial system in which defendants should and do have the right to their own impartial evaluation. Good documentation simply affirms the investigator's neutrality.

Given these concerns for scene and evidence integrity, we will consider the following areas that define proper documentation:

- Collection and detection of bloodstains and traces
- Photography of bloodstains, including video tape recordings
- Sketching techniques
- Written reports for bloodstain documentation

Collection

It is not enough that the analyst recognize a pattern as defining some specific action. Without knowing "who" was involved, this knowledge does little in defining a reconstruction. Bloodstain evidence does not stand alone; in particular, serology evaluations are critical to understanding the relationship of bloodstains to the crime.

The vast majority of jurisdictions utilize DNA analysis for determining whether a given sample from the scene is consistent with a particular individual. Forensic laboratories use polymerase chain reaction (PCR) or short tandem repeat (STR) preparation techniques. Both methods require a level of care in collecting and storing the specimen in order for it to be of value.

Beyond documenting the stain's location, as a rule the analyst should be concerned with five issues in collecting stains for subsequent serology analysis. These include:

1. Proper discrimination between stains
2. Sufficient identification of samples to patterns
3. Sufficient collection of samples
4. Precluding cross-contamination of samples
5. Sample collection prior to destructive testing

The first concern is really the investigative benchmark. Failing to discriminate if a given stain belongs to a specific pattern will cause the serology information to be useless to the analyst. In approaching each pattern for collection of samples, the analyst needs to be confident that the stains selected are representative of that pattern and only that pattern.

If several spatter patterns intermix in a given area, one cannot arbitrarily select stains from the conglomerate. Always choose the stains carefully to preclude later confusion.

In addition to having confidence that the analyst is collecting stains from a single pattern, the recovered samples must be marked in a fashion that will guarantee relating them back to that pattern. Ensure that the evidence collection notes and report have a clear correlating label that identifies the stain group involved. The authors prefer establishing a number for each stain group early in the scene processing. Any subsequent mention of the pattern includes a reference to this number. This number is also listed on the evidence collection forms, along with other standard data. The following examples contrast this information with and without the use of the identifying pattern number.

Inappropriate Evidence Collection Example

Item #	Description
1	Stain, red in color, dried. Approximate dimensions 2 mm × 2 mm. Found on the west wall, about 2 ft from the floor. Stain scraped into pharmacist's fold and sealed. Fold marked RMG 1200 2 OCT 95.

This description certainly tells where the item was found and the analyst can later identify the stain using the evidence mark (initials, time, and date), but it fails to associate the stain to a specific pattern or group.

Appropriate Evidence Collection Example

Item #	Description
1	Stain, red in color, dried. Approximate dimensions 2 mm × 2 mm. From Stain Group 2. Found on the west wall, about 2 ft from the floor. Stain scraped into pharmacist's fold and sealed. Fold marked RMG 1200 2 OCT 95.

This description provides all of the previous information but adds a ready reference to the stain group the analyst identified in the crime scene documentation as Group 2. This simple addition to the documentation effort can eliminate subsequent controversy regarding whose blood is involved in which patterns.

Sufficient collection of blood samples is also an important issue. Remember that no single person's effort helps the bloodstain analyst more than those of the serologist. Don't hamstring that effort. Cutting corners while collecting samples at the crime scene may save a few moments, but it will prove costly in the end. Take the time to provide the lab personnel with sufficient samples to do their job.

The authors asked a group of practicing forensic scientists to comment on methods of collecting bloodstain samples.* We felt we could obtain a consensus of opinion on the "best" method for collection. Unfortunately, there was no true consensus. From organization to organization the methods of collection differed. Some experts believed liquid blood should never be collected from the scene, while others felt it an appropriate response. Some felt scraping dried stains was a good method while others felt swabbing was more effective. Since there is no consensus for the collection of samples, it is imperative that

* The question was posed to the members of the FORENS-L Newsgroup on the Internet.

individual analysts coordinate their specific collection techniques with their own crime laboratory. This will ensure that whatever method is used meets the needs of the supporting serology department.

No matter what method is used, collection techniques should preclude cross-contamination and, depending upon the advice of the serology department, may require the collection of substrate and blank control samples. Substrate and blank controls are still considered applicable to DNA analysis, as they allow the serologist to recognize when contamination is present which may interrupt the analysis.

Whatever method is used, it is probably insufficient to collect a single sample from any given pattern. No matter what the size, issues of contamination or simply a degraded sample can result in an inconclusive serology report. The analyst should collect a fair sampling of stains (a minimum of two or three) from the pattern.

To prevent issues of cross-contamination, the analyst should exercise specific care in the collection process, following these general guidelines. First, use only new gloves and change gloves between patterns. Do not use standard "crime scene kit" tools for collection. Instead, use either disposable scalpels or single-edge razor blades for scraping, sterile swabs for swabbing, or disposable pipettes and syringes for collecting liquid samples. *Always* change the scalpel or pipette when moving from one stain to another.

Once recovered, the analyst must properly containerize the sample. Dried stains are best packaged in a druggist's fold, which is then sealed in another wrapping such as an envelope. Do not use the adhesive of the envelope unless forced to and, in those instances, wet the adhesive with sterile water. Never lick it! The adhesive alone will not seal the package completely. If the sample subsequently escapes the druggist's fold it may be lost from the envelope as well. Wetting the adhesive with other than water (e.g., saliva) opens opportunities for cross-contamination. A preferred method to using the adhesive is to seal the outer container completely with adhesive tape on all openings.

If liquid samples are collected from the scene, the vials or tubes need to be enclosed in a second container. Heat-sealed bags work well for this purpose. Should the tube be breached through spillage or accidental breakage, the heat-sealed bag may preclude the loss or degradation of the sample.

Items stained with blood, such as clothing, should be thoroughly dried. Once dry, individually wrap them in clean butcher paper. Use enough paper to encapsulate the entire item. If possible, do not fold the item directly over onto itself. It may be important to determine not only whose blood is on a particular item of clothing, but also where the blood is found on the item. Place an intervening piece of paper between the surfaces when the item is folded. This precludes the possibility of creating inappropriate pattern transfers and eliminates a source of cross-contamination if multiple DNA samples are present. Do not simply toss items of clothing into a bag or container, and certainly never toss multiple items of clothing into the same container.

Just as the analyst prefers that the actions of those processing the scene will not disturb the physical stains, so too the serologist prefers that the analyst not destroy the samples. The destruction of serology specimens occurs as a result of many factors, several of which the analyst cannot control. It only makes sense that we eliminate sources of degraded samples whenever possible. The use of many chemical enhancement methods, which were discussed in Chapter 12, represents a source for such degradation. Dr. Henry Lee demonstrated that many of these chemicals degrade standard ABO and enzyme serology tests. Although his research is not all encompassing with regard to their effect on DNA, it certainly indicates

a concern.[1] Never arbitrarily spray enhancement chemical on any item of evidence until after the collection of proper serology specimens or after coordination with the applicable serologist. If any questions exist on how to proceed, consult the supporting crime laboratory before acting.

Bloodstain Pattern Photography

Far too often crime scene photographs of bloodstain evidence are meager, insufficient in detail, and generally lacking. Simply put, photographers shoot from afar never filling their film plane with the image of concern. Unfortunately, most of the analysis process, and certainly outside analysis, requires detailed photographs. The information in this section is important to not only the bloodstain pattern analyst, but also crime scene technicians and investigators.

The challenge with bloodstain photography is recognizing the level of detail that is necessary. The technicians responsible for the scene photography may not understand the nuances of bloodstain pattern analysis. Unfortunately, their efforts at the scene can easily determine if any conclusion is possible at all. At times they document too much of the wrong thing, or worse yet, far too little of anything.

It is important to understand that not every drop of blood shed at the scene needs to be photographed. This approach is both time-intensive and expensive. Common sense and good judgment are the best guides in making such determinations. If a stain naturally causes questions in the technician's mind, it may be of importance in the ultimate analysis. If in doubt, however, take a photograph.

We offer the following guidelines as the minimum photographic documentation requirements:

- Document the entire scene *in situ*. Include overall photographs.
- Photograph evident pattern transfers, flows, and other fragile patterns early.
- Document all identified pattern groups or stains using evidence-establishing shots.
- Take macro-photographs of all stains of interest. Include a reference scale in each.
- In instances of spatter patterns where point of origin determinations are made, document the individual spatter used in the determination.
- Use Toby Wolson's Roadmapping method or a similar procedure.[2]

Documenting the scene is important no matter what the nature of the crime. Whether or not bloodstains are involved, the crime scene technician should photograph the scene immediately upon arrival. As a rule, these photographs include overall or 360° photos of each room to include the ceiling and floor. The technician, using a wide-angle lens (e.g., 28-mm), shoots across the room from each of the four corners or from any other configuration that captures the condition of the entire scene. All photographs of this nature should have some level of overlap with the next photograph.

Overall photos serve little function in the courtroom. The wide-angle lens causes obvious perspective distortion. Nevertheless, these photos are immensely helpful to the analyst and investigator, particularly when trying to verify where some item was at the time the processing began. As every crime scene technician knows, a primary goal is to

Figure 13.1 An overall photograph that establishes the presence of several patterns of interest on a kitchen floor (Patterns E, H, and I). The function of this photograph is to show an area and orient what is in the scene.

Figure 13.2 An overall photograph of a particular pattern. The overall shows both the pattern in its totality and acts as an evidence-establishing photograph for subsequent close-ups.

Figure 13.3 A close-up photograph of Pattern I-4, a pattern transfer, showing the detail evident in the pattern.

document the scene as found and eliminate the destruction, addition, or movement of items within the scene.

Questions regarding such actions will arise. Was the Styrofoam cup present originally, or was it added by the Chief? Was the bloody smudge on the wall caused by Officer Smith or the suspect? Was the chair in that corner or by the table? Overall photos help eliminate some of this confusion, which can plague the analysis or reconstruction attempt.

After taking the 360° or overall photos, the technician takes evidence-establishing and close-up photos of all obvious items of evidence. Establishing shots serve the function of identifying where in the scene a particular item is and any relationships it may have to other items of evidence. For example, Figure 13.1 through Figure 13.4 are scene photographs that take the viewer from an overall perspective of a grouping of major patterns (Patterns E, H, and I), to an overall of a specific pattern (Pattern I), and then to details within the individual stains that make up the pattern (Pattern I 1–4). Using these photos, the viewer realizes where the pattern transfer in question is in relationship to the

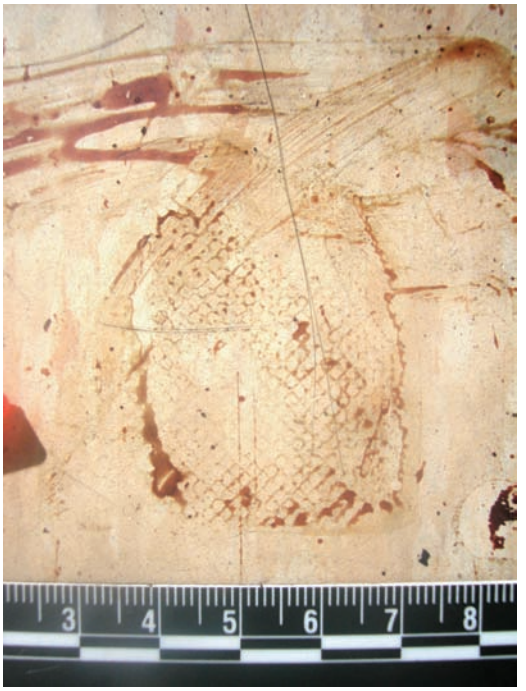

Figure 13.4 A second evidence close-up photograph filling the frame of the viewfinder with the specific details of interest. This second photograph is often necessary when the details of the pattern are small. In this case, the pattern appears to be associated with a shoe, and if that shoe were subsequently located, this photograph may offer the footwear examiner sufficient details to compare the two.

wall and floor. Again, this process should be done upon arrival. The photographer carefully moves through the scene, documenting the condition of all obvious items of evidence before anyone can disturb them.

As the analyst continues to process the scene using a standard processing model, photographs are made of all newly discovered evidence. The analyst can also take more controlled close-up photos as the item is actually collected. This helps document the item's complete condition.

Having discussed the general requirements for photography, let us return our attention to the specifics of photographing bloodstains. Pattern transfers in the scene and flow patterns are perhaps the most likely stains to fall into the "fragile" evidence category. Actions in the scene during processing can mar or obliterate them completely. Document these stains as soon as possible with close-up photography. Afterward, take all steps to protect the pattern from physical damage.

After all basic crime scene processing is complete, the bloodstain pattern analyst creates another series of photographs to support the bloodstain pattern issues using a technique such as Roadmapping (discussed in detail later in the chapter). These photographs capture all of the detail the analyst believes is necessary for the ultimate analysis and support of this analysis.

These photographs should also lead the viewer from overall picture to the detail. Figure 13.5 through Figure 13.9 depict a classroom exercise of what the basic objectives of this documentation should achieve.

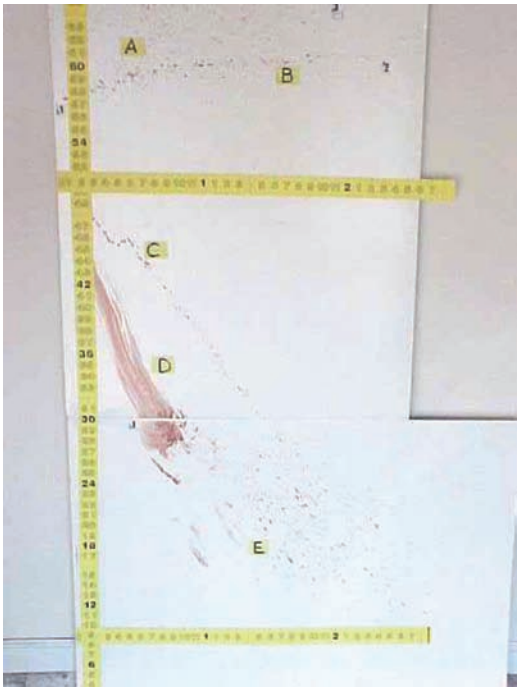

Figure 13.5 An overall photograph that orients the position of the various stains to the scene. By themselves, such photographs rarely provide the detail necessary for proper bloodstain pattern analysis, but they are still important as they allow us to orient each pattern of interest to the scene itself.

Figure 13.5 is the overall photograph of an area. It defines five distinct patterns of interest. These patterns are labeled A through E. The labels introduced by the analyst will help clearly show orientation of one pattern to the other and will help to orient this overall photo with others from the scene.

Figure 13.6 is an overall pattern photograph of a specific spatter pattern. The purpose of the pattern overall is to show the entire pattern, even if all detail is not evident. The photograph is taken from whatever distance is necessary to show the complete pattern. In smaller patterns, this photo will act as a close-up as well. In larger patterns such as this, close-ups will allow us to see that detail later.

Figure 13.7 is an overall pattern photograph of pattern D, a swipe mark. Once again, the purpose of this photograph is to document the entire pattern as it appears.

Figure 13.8 is an example of a close-up photograph intended to show the specific detail of Stain A1 from Pattern A. Note that it is annotated with a plumb line and a scale of reference. With the XYZ information obtained at the scene, this photo could be evaluated using a program such as Backtrack/Images.

Figure 13.9 is a close-up of detail present in Pattern D, specifically the presence of the bifurcations. This detail is important as it allows us to conclude the source of the swipe was hair or a hair-like object.

Each pattern of concern and the specific detail the analyst considers important must be captured in the photographs. Throughout the photography, each stain must retain an identity. A photograph with no landmark is of little value, as it makes it hard to be sure exactly what stain you are looking at or what the proper orientation of the stain is.

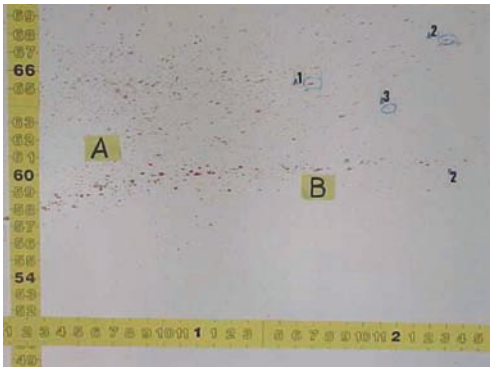

Figure 13.6 An overall photograph of a specific pattern, Pattern A, which is an impact spatter pattern. Similar to a scene overall, the pattern overall identifies the extent of a specific pattern. It may or may not show distinct detail, depending upon the overall size of the pattern of interest.

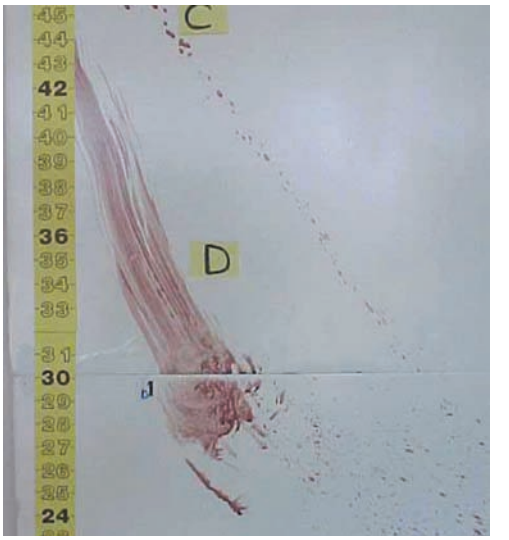

Figure 13.7 An overall pattern photograph of Pattern D, a swipe mark.

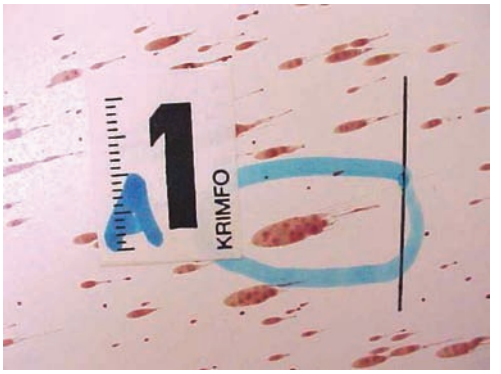

Figure 13.8 Close-up photographs of Stain A1, from the impact spatter Pattern A. These types of photos provide specific detail from the pattern or stain, allowing actual analysis.

Figure 13.9 Close-up detail in Pattern D, the swipe mark. Characteristics that are important and allow the analyst to include or exclude some particular mechanism as the source of the stain must be documented. In this instance, the small bifurcations in the upper right corner of the swipe allow the analyst to identify the source of the pattern as hair or a hair-like object.

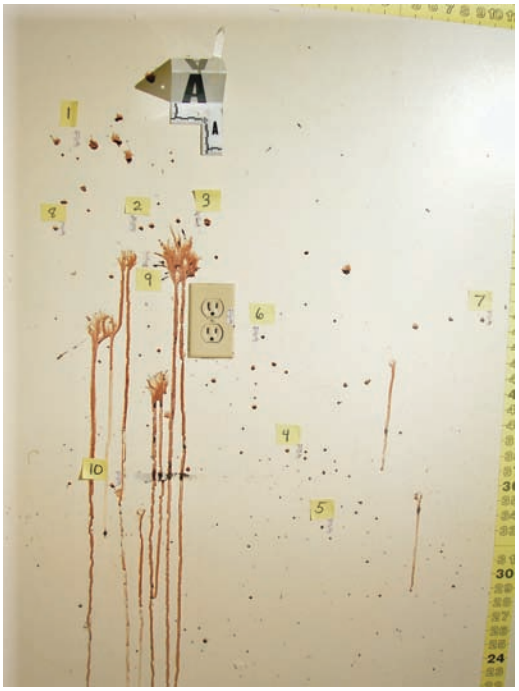

Figure 13.10 Another example of an establishing shot. In this instance, we can read the labels of the individual stains in question (Stains 1 through 10) and see their position on the wall.

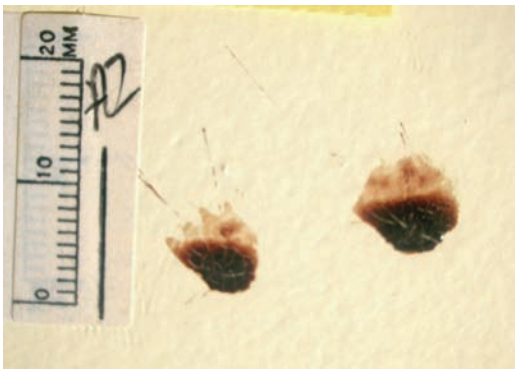

Figure 13.11 A close-up photograph of Stain 2 in Figure 13.10. Without the accompanying establishing photograph, it would be difficult for the viewer to understand this spatter's relationship to the scene.

Overall pattern photographs (e.g., Figure 13.2) often suffice as functional evidence-establishing photographs, so long as the labels introduced into the picture are readable. However, in some cases, such as when dealing with small spatter stains and other small bloodstains, it may be necessary to use several establishing shots, each successively closer to the stain.

Without the evidence-establishing photograph, patterns and stains lose context, particularly when viewed by others later on in the investigation. Consider Figure 13.10 and Figure 13.11. Without the establishing shot (Figure 13.10) the evidence close-up photograph (Figure 13.11) tells the viewer little with regard to where in the scene the item actually is. The same is certainly true for close-up photographs exposed of bloodstains on the evidence. The pattern evident in Figure 13.12 means little to the viewer without the accompanying photograph, Figure 13.13, which shows its location on the murder weapon.

The next step is to photograph the individual stains of interest. This means taking macro-photographs in which the film frame is filled with the detail present in the stain. Pattern transfers or swipes and wipes are all examples of stains that might be of interest.

Macro-photographs or evidence close-up photographs are taken with the lens inches, not feet, away from the stain. The close-up photograph of a pattern should have as much detail as possible. Camera orientation is critical in the close-up. Forget the fashion photography technique where the camera is shot at every conceivable angle. Place the film plane parallel with the plane you are photographing. Once that is done, fill the viewfinder with the subject.

Figure 13.12 An interesting pattern resulting from a beating death. The scale indicates the size of the stains, but where are they found and what relationship do they hold? Without an accompanying evidence-establishing photograph, Figure 13.13, the viewer has little with which to judge the significance of the pattern. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, OR.)

Figure 13.13 An evidence-establishing photograph for the Pattern in Figure 13.12. We now understand that the pattern is present on the murder weapon, a shelf from the kitchen. The weapon was used to inflict blunt trauma to the head of the victim. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, OR.)

Both of these concerns are imperative if the analyst wants clear, undistorted images of the patterns and stains.

If the scene involves spatter patterns and area of origin (AO) determinations are necessary, then photograph the individual stains used to make that determination. Again, this photo is taken with the lens inches away from the individual stain. Using this photograph, another analyst can measure the stain and verify its impact angle. This will effectively preclude any major challenge to the AO determination.

Evidence close-up photographs should be exposed both with and without a scale of reference in the photographs. When using the scale (e.g., when documenting spatter or droplets) it is best to align this scale along the length and width of the stain. This makes it easier to verify the dimensions from the photograph. To this end, Gardner developed the bloodstain photographic template (see Figure 13.14 and Figure 13.15).

The template has scales along two axes and a reference section that allows the analyst to identify each stain. A box is provided to align the template with either "North"

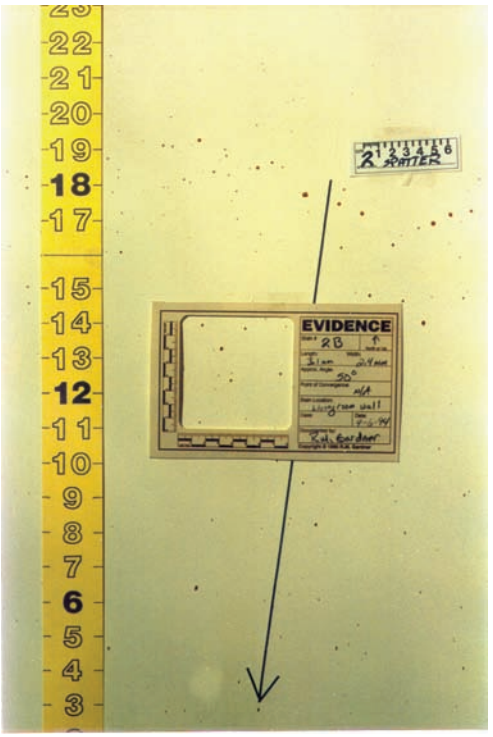

Figure 13.14 Using a bloodstain photographic template to document evidence. In this instance, the photograph is that of an establishing shot. When used to shoot evidence close-up photographs, such as Figure 13.15, the template is a subtle reminder to the analyst to fill the frame of the lens with the image. It also allows administrative data to be included in the photo with the stain.

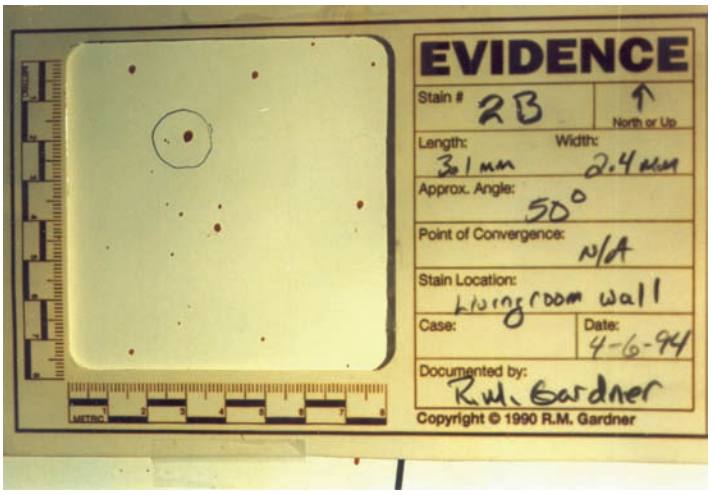

Figure 13.15 A close-up photograph of the spatter in Figure 13.14. In this instance, we include measurements of the individual spatter stain, which was circled, and indicate its apparent impact angle. An additional close-up photo is necessary as well, filling the frame with the spatter stain itself.

Figure 13.16 An example of the roadmapping technique. The large yellow scales allow the viewer to know where the various stains are on the wall. The placards are used to identify specific patterns, while the yellow labels identify individual stains of interest within the pattern.

or "Up," which is necessary if the analyst chooses to align the template scale with the droplet's axis.

Roadmapping is the most effective method of completing photographic documentation of bloodstains. It developed out of the efforts of Toby Wolson, a criminalist with the Miami-Dade Police Department, Miami, Florida. Although effective, it is also intrusive. To properly map the scene, the analyst must insert many "road signs" and scales for reference. For this reason, the analyst usually waits until the completion of the scene processing to complete this roadmap. Roadmapping is effective for documenting both still and video images.

When using Roadmapping, each major stain group is identified with a label, either a letter or number (e.g., Stain Group A) (see Figure 13.16). Individual stains or smaller patterns of interest within this larger pattern are given an additional identifier such as A-1 or A-2. Labels are taped or placed by each stain, using large lettering that allows them to be read from several feet away.

Adjacent to the pattern, the analyst introduces large reference scales to the surface involved. These scales are commercially available from many sources. For instance, on a wall the analyst places them along the side of the wall and above or below the stains. If needed, the pattern can be outlined by the scales.

Once in place, the analyst photographs the overall surface including the scales. The stain labels should be readable in these shots. The analyst then moves in and photographs the individual patterns. Finally, the individual stains of interest within the patterns are photographed. In any given photograph, the scales and labels should make it evident where

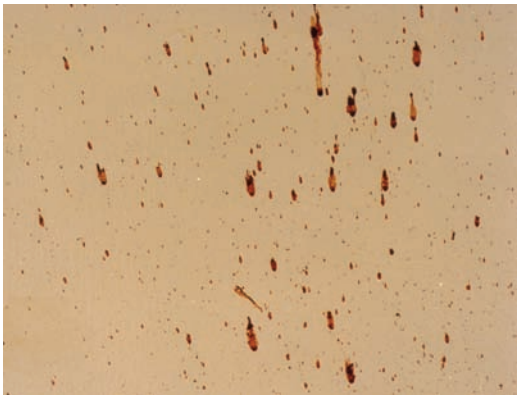

Figure 13.17 The typical close-up photograph found in most documentation files. Although the analyst often exposes such photographs without a scale or label, such photos do little in and of themselves to define the scene or identify the stain in question. In this instance, we have a spatter pattern, but no evident landmark. In effect, the viewer is "lost" in the scene with no means to associate the picture with its origin. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL.)

Figure 13.18 A Roadmapping example. Using the stain from Figure 13.17, this series demonstrates the function and utility of Roadmapping. In this photograph, we have an overall perspective that includes scales of reference, furniture items, and a Roadmap label. Although perhaps difficult to read in the reproduction, the individual stain labels were readable in the actual photograph. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL.)

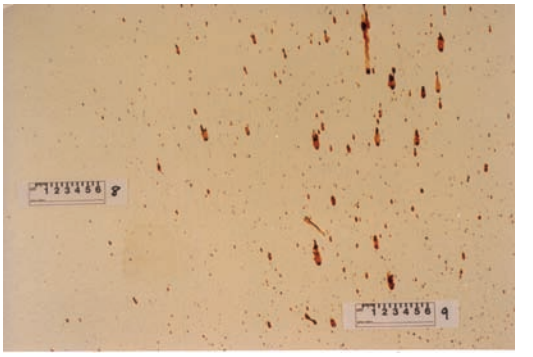

Figure 13.19 A close-up photograph of the spatter in Figure 13.17. Using two labels (Numbers 8 and 9) in conjunction with Figure 13.18, the viewer is able to recognize where in the scene the spatter is actually located. Roadmapping as a method moves the viewer from the overall perspective of the scene to the pattern and then to the detail in the pattern. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

on the wall or surface the analyst is looking. These labels are the "signs" on our roadmap. They preclude us from being lost (see Figure 13.17). To be effective, each photo should include at a minimum the individual stain label. Establishing shots are more effective if they show several of the surrounding labels. Figure 13.18 and Figure 13.19 document the spatter observed in Figure 13.17, using the Roadmapping method.

The analyst can also use graphic tape in addition to these labels to show indications of motions in swipes or wipes, or to show points of convergence of spatter and other

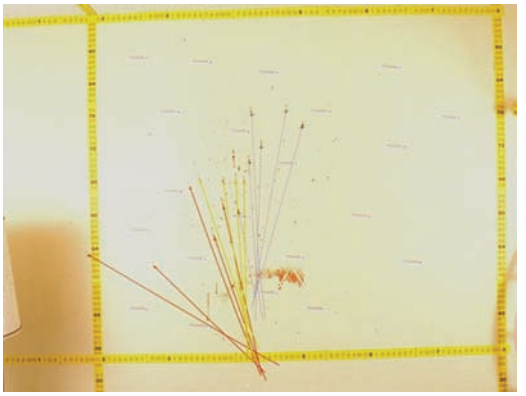

Figure 13.20 A continuation of the roadmapping method. This time the photographer introduces graphic tape to show a point of convergence for the spatter involved. For clarity, the headboard was removed and set to the side. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL.)

information that is deemed important. Figure 13.20 is an example of the inclusion of graphic tape in the Roadmapping process.

We cannot overemphasize how effective this method is for conducting subsequent analysis. Too often, the relationship of one stain to another is anything but evident in crime scene photographs. Roadmapping takes the viewer from an overall view to the pattern and then to the individual stains. Every photo graphically exhibits its relationship to other stains. It eliminates much of the viewer's confusion and also makes for outstanding case documentation. Roadmapping works not only for the scene but for later documentation of individual items of evidence. For instance, Figure 13.21 through Figure 13.23 show documentation of a bloodstained shirt using this method.

With the advent of the digital single lens reflex (SLR) camera, the analyst is now able to take and immediately evaluate the quality of all evidence photographs. Additionally, as the "film" is simply digital media, there is no limit to the number of photos that can be exposed on scene. If the analyst is not using a digital 35-mm SLR, he can still utilize a smaller digital camera to ensure that photographs exist of all evidence. Keep in mind that when working with standard film, mistakes can happen and it is possible to end up with over- or under-exposed photographs or, worse yet, no photographs at all. In the past, instant cameras were utilized to ensure that some level of documentation was captured. The digital camera is exceptionally functional in this role. Before leaving the scene, you know if you have the picture.

Our consideration of photography is also incomplete without discussing video. The video camera can be extremely useful in documenting a bloodstained scene. It serves as a functional method for documenting the scene *in situ*. A quick, non-intrusive walk-through of the scene can be invaluable later when the analyst is trying to verify the original condition of the scene. In combination with the scene photographs, video often clears up specific concerns regarding scene integrity issues.

After completing the scene processing, the video camera is also effective for overall documentation purposes. Using Wolson's Roadmapping techniques, the scales and "signs" are already in place. The analyst merely "walks" the viewer through the scene, showing the relationship of the specific stains to other items of interest. Combined with the

Figure 13.21 Roadmapping is just as effective for documenting items of evidence after collection. In this instance, we have an initial photograph of the overall item, framed by the large scales. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

Figure 13.22 In this second photograph of the shirt, an establishing shot, labels are introduced to identify the specific stained areas on the shirt. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

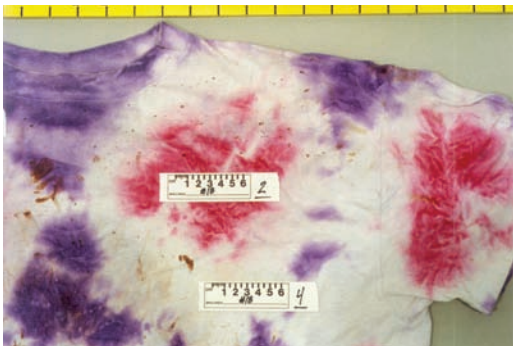

Figure 13.23 An evidence close-up photograph of Stains 2 and 4 on the shirt. By referring to Figure 13.22 and Figure 13.23, the viewer can easily determine the stain locations even if the collar were not evident in the photograph. (Photograph courtesy of Toby Wolson, MS, Miami-Dade Police Department, Miami, FL. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

Roadmapping process, this video can bring immense clarity to the situation. It provides the viewer a far better context in which to consider the scene.

One caution is appropriate to video camera usage at the scene. During the video taping, the analyst should limit narration to a description of the stains observed. Pursuing the "analysis" too soon in a taped medium may come back to haunt the analyst at a later date.

Scene and Pattern Sketches

Crime scene sketches are and will remain an integral part of scene documentation. They allow the viewer to "see" the relationship of where items of evidence were and where certain actions occurred, as well as help the court understand the overall circumstances of the crime.

All major stain patterns should probably be included in the crime scene sketch. They allow an individual who has never visited the scene to see relationships of one stain to another or to correlate a stain to its physical surroundings. The level of detail necessary for bloodstains in a sketch is entirely dependent upon the needs and desires of the analyst. We feel that all major patterns should be addressed in some fashion. This might only require the inclusion of the pattern label (e.g., Stain A) at the general location in which

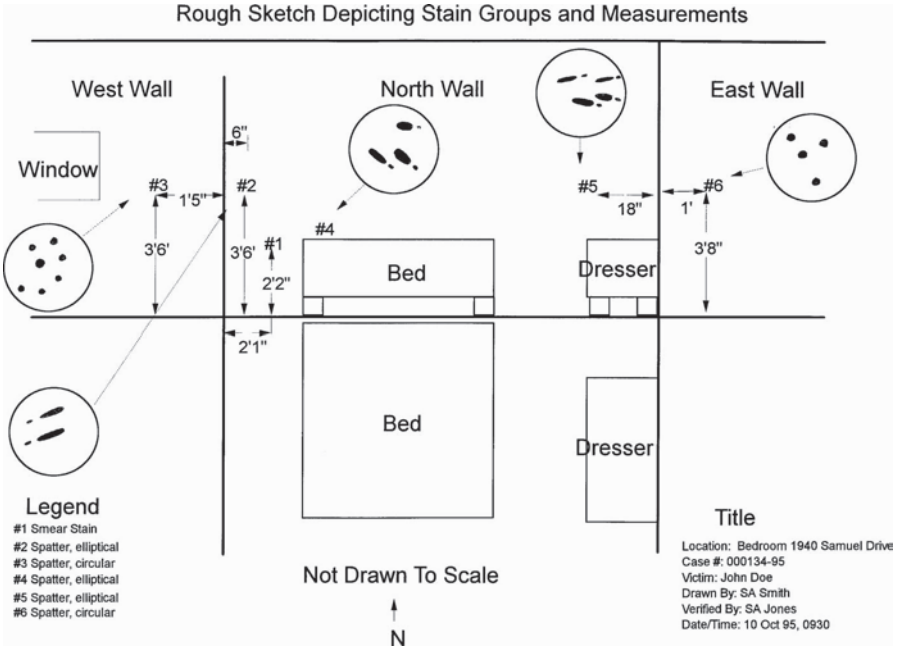

Figure 13.24 The cross-projection sketch. A cross-projection sketch allows the viewer to consider evidence present on various surfaces in the scene. For example, Stain Groups 2 and 3 indicate a common source of origin. This relationship might not be immediately evident to anyone reading the report without the cross-projection sketch.

the pattern was found, but this does not preclude the analyst from sketching any stain of significance into the drawing itself.

Oftentimes when considering a bloodstained scene, a cross-projection sketch is necessary to fully document the scene. In the cross-projection sketch, the analyst simply "lays" the surrounding walls down and appropriate stains and evidence are drawn onto them. This serves the function of relating one stain pattern to the location of another (see Figure 13.24).

As indicated, the analyst may choose to include only the labels of the stains present in the overall crime scene sketch. To provide greater detail, in addition to photographs, the analyst may wish to create individual sketches of stains of importance. Such sketches can include freehand drawings of patterns, patterns on clothing, or tracings of a given pattern.

Impact patterns in particular demand additional documentation effort, specifically in terms of crime scene mapping. If the analyst intends to conduct any area of origin or point of convergence analysis, each of the individual spatter stains chosen for inclusion must be documented fully. After choosing an adequate number of stains (which is generally defined by the nature of the pattern) the analyst must:

- Obtain close-up photographs that will allow other analysts to validate each stain's measurements.
- Locate each stain in the scene with physical measurements; this will demand a minimum of two measurements to place the stain on a given surface depending upon the measurement system being employed (e.g., rectangular coordinates, triangulation).
- Sample the pattern for DNA.

Written Reports

Photographs, sketches, and video tapes certainly enhance our overall understanding of the crime scene, but written reports are the foundation of investigative documentation. For that reason we should not approach the written report in a haphazard manner. The written report is the means by which analysts share much of their knowledge. It should be complete, methodical, and as objective as possible.

The first consideration in the written report should be to describe the information that serves as its basis. The analyst should describe the evidence that was reviewed and what actions were performed in support of the report. If all observations were made from photographs, the report should state this. If one section of the report is based on photographs and a subsequent section on photographs and on-scene evaluation, the analyst must make this clear. Consider the following example:

> Using photographs provided by S.A. Jones, I conducted an evaluation of bloodstains present at the scene of a rape/attempted homicide. Additionally, a review was made of all crime scene reports and crime scene sketches.

Major patterns or stain groups are then discussed in an orderly fashion (e.g., either by numerical order or perhaps in order of significance). This discussion begins with a complete description, which may or may not include a categorization of the stain in question. For example:

> **Stain Group #1:** This is spatter pattern present on the wall adjacent to the headboard.

This categorization is not speculative in any nature. For instance, one would not want to categorize such a pattern as expectorate blood vs. an impact spatter pattern; this is best suited for the conclusion. The pattern should then be described in detail, as in the following:

> The pattern is a spatter pattern. The majority of the stains are circular in nature with very few elliptical droplets. The stains in the pattern are primarily 1 to 5 mm in diameter. The majority of spatter present in the pattern are actually less than 2 mm in size. The pattern has no obvious linear aspect and there are no ringlets or vacuoles present. There is a radiating dispersion.
>
> This pattern is slightly offset on the wall above the single bed and slightly left of a large saturation stain on the bedding. The pattern's overall dimensions are 2 ft by 3 ft. The pattern begins at the level of the mattress and extends up the wall for approximately 2 ft. The pattern extends outward and left along the wall for a distance of 1 ft from the left edge of the headboard. The pattern extends across the wall to the right for another 2 ft. Based upon documentation provided, no specific point of origin recreations are possible.

There are generally two approaches as to where in the report the analyst should present conclusions. One approach is to present the conclusions at the end of the report in a conglomerate fashion. The following is an example of a conclusion sheet:

Stain #	Conclusion
1	Forceful bloodshed occurred near the east wall of the bedroom and within 26 in. of the floor.
2	Cast-off stain patterns seen on the ceiling describe an object wet with blood being swung in a right overhand fashion. These patterns correspond to the forceful incident described in #1.

Stain #	Conclusion
3	The subject was upright and in a seated position when blood flowed from her head wounds.
4	The subject was repositioned face down following the infliction of wounds to her head.[3]

Another approach is to simply include a brief conclusion regarding the individual stains after the description. For example, with regard to our Stain Group #1 such a conclusion might read:

> The spatter pattern on the wall is consistent with an impact spatter pattern. It defines an impact that occurred in the vicinity of the bed mattress. No other correlations are possible at this time.

The written report should give the reader a clear picture of what the analyst observed. Always seek to define specific characteristics that are evident in the stain. Ensure these characteristics are included in the report. The following are more examples of how one might document a stain. Without this type of detail, it is difficult for analysts to support why they reach the conclusions they do.

A Spatter Pattern Description/Conclusion

Stain Group 2: This is a spatter pattern present on a nightstand adjacent to the left side of the bed.

The pattern is made up of circular and elliptical shaped stains the largest of which is 5 mm in length. Smaller spatter measure down to the 1.5 to 2 mm range with other smaller spatter present, but too small to measure based on photos alone. Most of the spatter are circular stains on standing articles on the nightstand (e.g., a pitcher, cloth, and bottle). The number of stains is in excess of 100. Those present on the upper surface of the nightstand itself are elliptical and struck the surface at extreme acute angles. The pattern radiates across the nightstand top R-L.

A void/demarcation line is evident in the stain group. This void is evident on a plastic cup behind the pitcher and is also present in the elliptical stains on the upper surface of the nightstand.

Something at the point of the pitcher, either while present on the bed or nightstand, precluded spatter from occurring on the remaining items.

Directionality of the elliptical stains places the origin in the vicinity of the large stained area on the bedding.

Extending the directionality of several of the elliptical stains on the nightstand, a point of convergence in two-dimensional space would be approximately 16 to 18 in. to the right of the bed mattress edge. Once again, this correlates with the observed saturation stain area on the bed mattress.

A Blood Pool Description/Conclusion

Stain Group #3: This is a large liquid pool present on the floor near the entrance of the cubicle in the room.

The pool is diluted, but the nature of the dilution is not immediately evident.

Lower sections of the stain show spines, indicating the application of force to the liquid. There is little to indicate the nature of this force itself.

The upper right-hand section suggests linear features which may be more spines. Within the lightest section of the stain (in the central area) is a threefold linear marking.

This stain is not disturbed except for the spines discussed on the edge which faces the bathroom. There are no foot or shoe marks in the stain and the general boundaries are intact.

The blood present within the stain is not the result of drops impacting, either as venous bleeding or spatter. No indication of drips or drip pattern satellites is evident around the stain. The pool received several forceful impacts of some nature, causing the spines. The pool was undisturbed on the side nearest the bathroom, meaning it was deposited and then no further action occurred to that side.

A Pattern Transfer Description/Conclusion

Stain Group #7: This group includes numerous contact stains deposited on the pillowcase. The entire pillowcase is saturated with blood, making many patterns marred or blurred to the point that they are of no value.

Within the outer boundary areas of the saturation, however, there are double parallel linear markings. Some of the markings are very short, while others extend for a distance of up to 3 cm.

Three general widths are apparent between these double linear boundaries: 4.6 mm, 19.7 mm, and 32.5 mm. These measurements were derived from Xerox copies of the stains, in which a 7% enlargement factor was determined and added.

On the pillowcase, there are one (1) set of lines that closely match the 32.5 width, two (2) sets of lines that match the 19.7 mm width, and five (5) sets of lines that match the 4.6 mm width.

These markings suggest a bloody object came in contact with the pillowcase. The manner of these sets of stains indicates a random application of the object to the pillowcase. There are many more linear features present on the pillowcase, but none provide specific characteristics beyond indicating an object with a bloody edge was in contact with the pillowcase.

There was one additional stain of interest, which lacked further identifying characteristics. The stain is a pattern transfer with a curved feature, perhaps a dual boundary. The curve is not typical of any objects evident in the scene (e.g., a bottle). The nature is insufficient for further identification without a specific object to compare it to.

A Complex Pattern Description/Conclusion

Stain Group #8: This group consists of a saturation stain on the upper sheet of the bedding and includes contact stains evident to the left of the saturation stain and spatter evident to the right.

The contact stains have distinct demarcations, indicating a pattern transfer with dual linear boundaries, similar to those found on the pillowcase. The linear stains range from a few millimeters in length to 11 cm. The application appears less random than that found on the pillowcase, with the majority of the lines angling downward from the saturation stain at about a 30° to 40° angle.

The patterns exhibit the same measurements as those on the pillowcase. There are two (2) sets of lines that match with the 4.6 mm width, and one (1) set of lines that match with the 32.5 mm width. Impact spatter is evident throughout this stain. Directionality for these limited stains is difficult to determine due to the cotton material.

The spatter evident to the right of the saturation stain is comprised of an area of 8 in. × 3 in. The spatter range is 0.2 mm to 2.4 mm. The definition evident in the stain and radiating effect evident in the spatter point to a single action as the source of this stain. The force that created this stain projected the droplets at about a 45° angle down and out from the top edge of the sheet.

The same object that came in contact with the pillowcase also came in contact with the sheet. In doing so, it was better defined (e.g., length at least 11 cm).

The nature of the conclusions and the level of certainty described in the body of the report are always a major concern. As Bunker said, "This is a report which will be examined, reexamined, and dissected by others."[3] If you are not confident that you can support your findings, then do not include them.

Summary

Documentation of bloodstains at the scene is truly an important function. Without quality documentation, the analyst may doom any subsequent analysis to failure.

Documentation considerations include the proper collection and preservation of evidence. This demands the analyst understand the needs and desires of the serologist. It also requires an understanding of the chemical detection and enhancement procedures available including their limitations, which were discussed in Chapter 12.

Graphical documentation in the form of sketches and photographs are equally important. They must clearly show stain detail and define where in the scene the stain was. Without this detail, the analysts are limited in their conclusions. Without knowing where in the scene the stain was, it is difficult at best to make any rational decision about the overall reconstruction. Written documentation is the true backbone of the overall documentation effort. In Chapter 14 we will provide the analyst with a format for documenting a "reconstruction," but the scene documentation itself must be clear, concise, and detailed. Full descriptions of what the analyst observed are imperative. Each stain should be fully described in a logical order that leads the reader through the scene.

No matter how well intentioned an investigation may be, in the end it will be judged on the analyst's documentation. The analyst's efforts at documentation cannot be haphazard.

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An Introduction to Crime Scene Reconstruction and Analysis

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At the beginning of this book, we indicated that bloodstain pattern analysts are reconstructing crimes. They may concentrate on only one aspect of crime scene reconstruction, but it is impossible to act as a bloodstain pattern analyst and not foray into the world of crime scene analysis. For this reason, it is important that all bloodstain pattern analysts understand the tenets of crime scene analysis and reconstruction. They may not choose to pursue a full-scale crime scene analysis, but they should understand how a full-scale analysis is accomplished.

Although many individuals with varying mindsets bandy about the words "crime scene analysis" and "crime scene reconstruction," these terms have specific meanings and contexts. The Association of Crime Scene Reconstruction defines reconstruction as "the use of scientific methods, physical evidence, deductive and inductive reasoning and their interrelationships to gain explicit knowledge of the series of events that surround the commission of a crime."[1] For purposes of this text, one may consider crime scene analysis and crime scene reconstruction as synonymous. Later in this chapter, we will introduce a methodology known as *Event Analysis*. All three terms relate to the same idea and entail the application of scientific method to the scene data in order to identify specific actions taken during an incident. Whereas crime scene analysis and crime scene reconstruction are general terms for this process, Event Analysis is simply a methodology by which one can accomplish it.

Specific actions are identified by considering the physical evidence at the scene as well as the context in which it is found. By identifying specific actions that occurred, in effect the analyst identifies *what* happened. Just as important to us, an examination of the scene can also lead to objective statements about *what could not have occurred*. But defining the *what* of the crime is not the only consideration of crime scene analysis; whenever possible crime scene analysis defines the order in which the crime happened. The end product of crime scene analysis is an objective statement of specific actions that occurred sequenced by the order in which they occurred.

Keep in mind that issues of *why* something happened are not on the table for the crime scene analyst to consider. Physical evidence cannot answer why someone was stabbed fifteen times (unless someone left a confession and even then the confession must be viewed for what it is, subjective testimonial evidence). The crime scene analyst's event horizon is the *why* of crime; it is a point beyond which we cannot see. Physical evidence will tell us much about what happened (e.g., where and how the victim was stabbed), but the intent of an individual's mind is not transferred into or viewable through physical evidence, at least not objectively. Leave such opinion for the psychologists. Absolute claims about why someone did something by a crime scene analyst are nothing more than speculation.

The end product of crime scene analysis however is quite useful. If we can effectively establish that certain things did not occur or that certain things did occur and be confident of the general order in which these actions occurred, such knowledge can be considered against any known statements or theories. The analysis is contrasted against these theories (e.g., investigative, prosecution, or defense theories) or statements by involved

parties. When compared against the reconstruction, either the statement or theory will be supported or some part or all of it will be refuted. Wherever the crime scene analysis is found to be out of sync with a given statement or theory requires that aspect of the theory to be revisited. If the analysis was conducted properly and all known information considered, the theory or statement must be incorrect in that aspect. Another important use of crime scene analysis is before the court and jury. Judges and jurors are asked to evaluate various theories and decide which they believe is accurate. They must listen to and ultimately place a value judgment (e.g., do they believe the witness or not?) on all of the testimonial evidence presented. Obviously, the analysts cannot invade the jury's providence, but through their testimony they can highlight the "what" of the incident in question, which will allow the jury to better evaluate what they are being told. Crime scene analysis provides the jury with objective information on which to base such decisions. The analysis becomes a benchmark against which any statements or claims can be tested.

Crime Scene Analysis and the Archeologist's Dilemma

Crime scene analysis is often discussed in a jigsaw puzzle analogy, something we first referred to as the archeologist's dilemma. The authors once heard an archeologist explain his professional pursuit as something like putting together a jigsaw puzzle. His dilemma, as he described, was like having someone walk up to him, throw down several handfuls of the puzzle pieces from the puzzle box, and then watching as they threw the box top and remaining puzzle pieces away. Using only the pieces of the puzzle provided, the archeologist was still expected to answer, "What does this picture look like?"[2] This puzzle analogy is true for the crime scene analyst as well; in fact, the crime scene analyst shares exceptional correlations in his pursuit with the archeologist. So much so, we will apply basic principles from archeology to crime scene analysis. No doubt, some may ask if this is a fair association.

Consider that archeologists examine historical sites in detail. They document the scene context using detailed notes, photographs, and sketches. Artifacts are carefully recovered from the scene in order to preserve their value and context. Archeology expects much from the scene documentation. This includes:

- The documentation must provide a clear and accurate description of all features that will disappear as a function of the excavation.
- The documentation must allow for the organization and identification of each artifact removed from the scene.
- The documentation must allow for the correct reconstruction of the strata and artifacts recovered.[3]

An axiom in archeology states: "To excavate is to destroy"; thus, documentation of the scene is considered critical to any subsequent understanding.[4] The physical artifacts recovered are then examined in depth, oftentimes by other scientific experts in an effort to understand what they are and what they define. Then using all of this data, the archeologist attempts to identify specific conclusions regarding what happened and in what order things happened at the site involved.

The crime scene analyst and crime scene technician follow similar paths with similar expectations. Crime scenes are examined in depth. Scene context is documented using

notes, photographs, and sketches, with the recognition that any action taken in the scene has an effect on that context. Artifacts (evidence) are recovered and examined to define what they can tell us. When needed, the evidence is examined by other experts in order to better understand its nature. Then using all of this information, the crime scene analyst attempts to identify what happened and in what order it happened. The only real difference between the tasks of the archeologist and crime scene analyst is found in the age of the sites involved. The crime scene analyst deals with far more recent history; thus, we typically have more artifacts and as a rule a better overall scene context to consider them against. Archeologists are not crime scene analysts any more than crime scene analysts are archeologists, but our point should be clear: We share similarities in task. Therefore, crime scene analysis can draw on established principles of archeology to assist us in our pursuit.

Like the archeologist, each artifact discovered at the crime scene becomes a piece of our jigsaw puzzle. No single piece answers all of our questions, but each piece tells us something. Each piece becomes a data item that may ultimately allow us to state with some level of certainty that something did or did not occur. Seeking interrelationships between the various pieces of our puzzle allows us to begin to piece together a picture of the incident, our box top. How conclusive that picture is or is not is very much a product of the evidence available. Even though the theory of crime scene analysis is that "nothing just happens," we are still limited by technology. Not every action leads to a recognizable artifact, something the analyst can observe and recover through current technology. Like archeology, the greatest limitation in crime scene analysis is there are only so many pieces of the puzzle available in our scene to find and use.

Adding to this dilemma is a concern for recognizing what pieces actually belong to our puzzle. Not only must the analyst understand how the various pieces of the puzzle fit together, he must also work through and recognize which pieces are from some other puzzle. Remember that no scene is ever really clean or fresh. Every site has some history; thus, there may be artifacts present that are associated with some prior incident or something that was simply present when the incident occurred. The analyst arrives after the fact to find these pre-incident artifacts. Not really knowing what they are looking for, the analyst initially considers them as part of the puzzle being examined. Just the same, post-incident artifacts may be present, created by police, suspects, EMS, and witnesses. These items have nothing to do with the incident in question, but are present nonetheless when the scene is processed. All of these concerns have to be considered by the analyst in order to know what pieces of evidence he should be trying to put together.

Crime scene analysis is very much like a giant jigsaw puzzle, a daunting task that demands the application of specific methodologies. It demands objective analysis of all information, in which counter-theories are considered and evaluated with the same level of effort as the pet theory of the hour. The analyst must recognize that no matter how smoothly the investigation proceeds, in the end what we know from the scene is sometimes less than what we do not know. In part, this limitation is based on the available evidence. To accomplish the reconstruction we have only the evidence discovered and evaluated, and that evidence provides us with but a mere glimpse of the actions and events that encompass the crime. If this glimpse is accomplished using a valid methodology, the end product is invaluable to everyone's understanding of what actually happened.

How limiting is this task? Consider the Rodney King incident that occurred in Los Angeles in 1989. In the subsequent trial, jurors had to decide if the police officers acted appropriately during the apprehension. In this particular instance, the jury had

an advantage, a videotape of many of the critical portions of the incident. The problem seemed simple enough: watch the tape and decide who was right and who was wrong. For example, was Mr. King struck full force in the face by a baton? The opposing counsels presented convincing evidence claiming completely opposite positions.[5] Even with the tape, decisions of whether this action transpired were anything but simple.

Investigators rarely have the luxury of a videotaped beating, shooting, or murder from which to develop a concise picture of the actual events involved. Lacking such evidence, the court still expects us to shed light on what did or did not transpire during any given incident. We attempt to do this by using whatever evidence is available. In viewing our scene to define these actions, the evidence encountered will likely fall into one of three broad categories. Without alluding to legal definitions, we might name these categories direct, circumstantial, and peripheral.

Direct evidence is that which gives us clear direction and focus relevant to some action. These kinds of facts are indisputable by anyone. For example, a contact gunshot wound indicates the weapon was in contact with the victim. Thus, whoever operated the weapon must also have been in an appropriate proximity. A latent fingerprint tells us that the depositor of the latent had contact with the item on which it was found. This type of evidence speaks clearly and concisely to everyone.

Following direct evidence is circumstantial evidence, which provides direction but lacks distinct focus. How the information is used in the analysis may be arguable from several positions. Consider a swipe pattern made with the victim's blood. Obviously, it occurred after the victim received some bleeding injury, yet the specifics of who made the swipe and how it was made may still be lacking. This evidence is important, but it demands that we carefully consider any conclusions we draw from it.

On the heels of this second category comes peripheral evidence. Consider a single hair or fiber found at the scene. Can we relate it to the incident or is it perhaps some accidental deposit totally unrelated to the situation being investigated? This type of evidence may or may not assist in the reconstruction. The problem is in determining where and how it fits into the overall picture. Nevertheless, it may be critical to our understanding of the event. More often than not, this type of evidence creates major distractions, not only during the investigation, but also in the subsequent judicial proceeding. As we are not always clear as to how it relates to the scene, wild claims by counsel are often made regarding that relationship.

In pursuing a reconstruction, just like the archeologist we seek to define physical events that we were not present to observe. Therefore, we must always remember that:

- These actions are dynamic. This is to say that any number of similar actions may produce a result, which we observe. These similar actions, however, may deviate in slight but important ways.
- The nature of the evidence to support our decisions on these actions, even in the best of circumstances, will probably provide only a glimpse of this past.
- Rarely will we have a standard to which we can objectively compare our conclusions. There is no investigative box top available for the analyst to refer back to!

Therefore, neither we, nor the court, can ever be absolutely certain as to all of the specifics encompassing an incident. We may be able to define individual moments with near-absolute clarity, but in the end, our overall picture is simply the best explanation given the evidence available to us. For this reason, we should never attempt to define

too narrowly the actions surrounding an incident. Our responsibility is to make this an objective picture, inferring as little as possible.

A History of Crime Scene Analysis

Although the authors are working to reshape and focus the practice of crime scene analysis, the concepts behind it are not new. Just as bloodstain pattern analysis has a rich history, there is a significant history in forensics relating to reconstructing criminal events using physical evidence. Although the methods were not well documented in some of the earliest references, clearly investigators have and continue to apply formal methodologies to this task.

The basic methods associated to crime scene analysis have been described in investigative texts for over 100 years. In 1900, Hans Gross spoke of the necessity of reconstructing the crime through a meticulous examination and collection of facts. He warned the investigating officer that by heaping testimony upon testimony, they will "almost always be led astray and found wandering from the goal [the truth]."[6] Although Gross described his beliefs across his entire text and did not present them as a specific methodology, he discussed every aspect of our current beliefs. This included the necessity of making detailed crime scene observations, scientific examination of physical evidence in an effort to obtain as much objective data as possible, and applying this information to specific questions regarding the crime in an effort to "reconstruct the occurrence, build up by hard labor a theory fitted in and coordinated".[7]

In 1933, Luke May wrote *Scientific Murder Investigation*. May outlined a series of questions that should be answered in the investigative process, but while leading his readers to the questions he described the process of the investigation itself. May used an analogy other than the jigsaw puzzle. He likened the investigation to building a structure; stating that without plan and direction, only the simplest of structures was possible. He said that a murder investigation was like building a skyscraper; without planned effort and an underlying superstructure, successful completion was impossible. May was clear in describing that investigators must "develop other facts, correlating and interlocking to make a whole from apparently disassociated separate units."[8] He also warned of allowing subjective personal theories to guide the investigation and the all too common habit of trying to force the pieces of the investigation into such theories. May stated the true mark of the scientific investigator was one who could "work untiringly, obtaining facts upon which to predicate theories, changing his theories as the facts developed warrant."[9] May did not spell out a specific crime scene analysis methodology, but his beliefs set a clear foundation for such a methodology.

Another pioneer in crime scene analysis was Edward Heinrich, known as the "Wizard of Berkeley." Heinrich offered one of the first true methodologies. He felt that one must first analyze the method of the crime before one could properly understand its purpose or hope to identify the criminal. He described reconstruction as "…visualizing the habits and actions of the criminal. I do this by using the debris [evidence] that the criminal leaves behind and relocating it with respect to the criminal episode."[10]

Heinrich likened his analysis to "a mosaic…every fact must be evaluated before it can be fit into the pattern. In that way every fact as it is developed and equated becomes a clue."[11] Heinrich's methodology was basic and included defining what happened, where it happened, and when (in what order) it happened. Heinrich felt the information developed

from the crime scene analysis would ultimately lead to answering the more subjective questions of why it happened and who did it.

In 1933, Henry T.F. Rhodes made the case that crime scene analysis was a specific scientific process. In his text, *Clues and Crime*, he indicated that the objective of the crime scene evaluation was to decide specifically how the crime was committed and in what order the events occurred. Rhodes was also clear that scientific method was the underlying foundation of any such analysis.

Charles O'Hara published *Fundamentals of Criminal Investigation* in 1956. This text was a standard in many academic criminal justice programs for a number of years. O'Hara placed a significant emphasis on the objective value of physical evidence and its scientific evaluation. He spelled out a specific methodology for crime scene investigation using scientific method, stating it involved:

- Painstaking and comprehensive collection of data
- Arrangement and correlation of that data
- Defining issues and investigative questions
- The development of a hypothesis along the lines of the available data and subsequent resolution of any hypothesis
- Testing of the hypothesis and elimination when possible of contradicting hypotheses
- Testing of the final hypothesis before acceptance[12]

O'Hara offered these ideas as a "representative approach" to the entire investigation, including subjective aspects such as testimonial evidence. Nevertheless, like others before him, he was very clear that physical evidence and the crime scene shouldered a distinct responsibility in solving crime. In addition to his representative methodology, O'Hara made the case for conducting a separate crime scene reconstruction.[13] In his fourth chapter, O'Hara discussed reconstructing crimes, indicating the reconstruction was accomplished through both physical and mental methods. He stated:

> Subsequent to search of the scene an attempt should be made to determine from the appearance of the place and its objects what actually occurred and particularly what were the movement and methods of the criminal… The process of ascertaining the circumstances of a crime is known as reconstructing the crime… From a study of the evidence in this manner it is often possible to make useful inferences which may be synthesized into a reasonable theory… In reconstructing the actions of the criminal, the investigator should test his theory for logic and consistency. A theory should not be rejected merely because the investigator might not, under the circumstances, behave in a similar manner… No assumptions should be made concerning actions which are not supported by evidence.[14]

James W. Osterburg wrote his text, *Criminal Investigation, A Method for Reconstructing the Past*, in 1992. Osterburg made it clear that the investigative process must follow the scientific method, and although he did not define a specific reconstruction methodology, he discussed the importance of using physical evidence to reconstruct events.

Perhaps the first detailed methodology for reconstructing crime was presented by Rynearson and Chisum in 1989 as part of their work *Evidence and Crime Scene Reconstruction*. Their ideas and concepts were a significant step forward. Of particular interest was their statement that the true value of evidence is a function of time and surroundings.

This statement effectively means that context has greater value than mere content. For instance, finding a fingerprint in the scene may be important, but of greater importance is the context in which we find the fingerprint. Context is critical in crime scene analysis and Rynearson and Chisum understood this. Their described methodology used what they referred to as a storyboard approach, a means of identifying specific events and their sequence or order.[15]

Dr. Henry Lee wrote his text, *Crime Scene Investigation*, in 1994. Lee included a specific chapter on reconstruction, in which he commented on the importance of using all forensic disciplines as input to any reconstruction. Lacking in Lee's work was a discussion of his methodology. He offered only that scientific method was the underlying process to a reconstruction, but failed to give a practical understanding as to how one achieves the reconstruction with scientific method.[16]

What we find through an examination of all of these works are certain common themes regarding analysis. These themes can be stated as:

- Data defines the conclusion.
- Objective data is found at the crime scene in objects and scene context, whereas human testimony should always be viewed in a cautious fashion.
- Effective forensic evaluation of evidence leads to refined data, which in effect leads to conclusions that are more refined.
- That "what happened" is not the only question of crime scene reconstruction; the issue of "in what order did it happen" is a critical component of any crime scene reconstruction attempt.
- Crime scene analysis uses reductionism; it is a bottom-up approach, where the analysis is reverse engineered from the physical evidence.

Whatever methodology one chooses for crime scene analysis, these themes must be incorporated into it.

Chisum subsequently contributed a chapter to Brent Turvey's book, *Criminal Profiling*, entitled "An Introduction to Crime Scene Reconstruction," and in 2007 co-authored *Crime Reconstruction* with Turvey. Unfortunately, they did not take the opportunity to expound on previous beliefs, and in the latter reference Chisum appears to have abandoned his previous methodology for a concept he calls Evidence Dynamics, a laundry list of things to ask regarding how the evidence was handled after collection. Although they suggest a form of crime scene analysis, it is in our opinion severely lacking. Evidence dynamics is skewed far more to what cannot be done, as compared to what can be done. Further, they state:

> When the reconstructionist identifies a discreet event, it is placed where it fits within the elements of the crime. This provides the foundation for the sequence of events and keeps them in order. In this fashion, the *time line* [italics added] expands from a sequence of general elements to a sequence of discrete events.[17]

Crime scene analysis recognizes the distinct difference between time (known as absolute chronology) and sequence (known as relative chronology). In crime scene data, time associations are few. A time line is a specific investigative product, which is certainly associated to an event sequence but they are not the same. One of the greatest failings in crime scene analysis is in attempting to do exactly what Turvey and Chisum suggest. Identified

actions (in Turvey and Chisum's words "discrete events") can rarely, if ever, be time associated to every other action and put into a specific time line. Even if one presumes that Turvey (a criminal profiler) was attempting to describe sequencing these actions, sequencing actions to every other action is rare as well. As we will see, flow charts that describe the sequence of actions are often convoluted documents. They routinely have many branches. One branch may describe a sequence for a series of related actions but show only a general sequential relationship to other branches. A direct relationship between every action on the various branches is rarely possible. Granted, Turvey's background in criminal profiling very likely influenced some of his understanding of the practical application of crime scene analysis. The development of criminal profiling methods in the 1980s served as a catalyst for bringing crime scene reconstruction back into the forefront of investigative literature. Nevertheless, this association has created significant misunderstanding of what crime scene analysis really entails.

The Correlation of Crime Scene Analysis to Behavioral Analysis

Criminal profiling provides a service in serial and violent crimes, which may assist the investigator in narrowing the search for a suspect. This evaluation, which considers the crime scene, the victim's actions and background, and the apparent actions of the suspect, provides information that may define the individual as a suspect. The information derived from the process can be valuable. It is also a subjective process and a good profiler usually explains to the prospective client that these methods are not without fault and are anything but completely accurate. In one case known to the authors, the profile identified 12 characteristics of the probable perpetrator. When the suspect was caught, none of the 12 matched. The primary reason for this disparity was that the case involved a female serial killer who decapitated her victims, a circumstance that fails to fit the statistical data used in developing such profiles.

Our discussion of crime scene analysis concentrates on the evaluation of the scene and physical evidence, considering specific facts and any information we may safely infer from those facts. We base such an analysis primarily on physical evidence that has been tainted as little as possible with subjective information. Our position is that having defined the reconstruction in this fashion, one may always expand to consider the more subjective information available and any hypotheses based on such information.

Criminal profiling is an important function in the criminal investigation, one that is inseparably linked to crime scene analysis. The evolution of criminal profiling techniques has been significant over a relatively short period, but as Geberth noted, psychological profiles are nothing new to criminal investigations.[18]

In early criminal investigations, most profiles were completed after the suspect was in custody. More often than not, these methods applied standard psychiatric approaches to establish the sanity of the individual involved. Heinrich, as reported by Chisum, was perhaps the first criminalist to go beyond scientific analysis of evidence in his efforts and develop an early form of profiling. Heinrich's methods included consideration of the scene as well as victimology.[19]

Another notable exception to the post-arrest psychiatric approach to profiling was the effort of Dr. James A. Brussel during the 1940s to 1950s. Dr. Brussel used his psychiatric training in an attempt to identify personality characteristics of the individual known as

the "Mad Bomber." This individual set off more than 30 bombs over a 16-year period. As reported by Geberth, Brussel's evaluation after reviewing investigative efforts spanning those 16 years said simply:

> "Look for a heavy man. Middle age. Foreign born. Roman Catholic. Single. Lives with a brother or sister." He [Brussel] also added, "When you find him, he'll be wearing a double breasted suit. Buttoned." [The suspect] was exactly as described by Dr. Brussel. When taken into custody he was even wearing a double breasted suit.[20]

Brussel went on to apply these techniques in other investigations including the infamous Boston Strangler case.

In terms of its relationship to the crime scene analysis and reconstruction, the most significant evolution of profiling came about with the work of Howard Teten. Influenced by previous efforts, but with a greater understanding and appreciation of the role of all forensic disciplines, Teten developed the initial FBI profiling techniques. Over the next 20 years those techniques were tweaked and enhanced, creating a process that is now, as Turvey says, a "multi-disciplinary skill."[21]

Modern criminal profiling generally consists of three stages. These are:

1. Collecting profiling inputs: these include the crime scene, victimology, forensic information, police reports, background information, and photos.
2. Creating decision process models: defining the homicide style, primary intent, victim risk, offender risk, location, and escalation.
3. Conducting a crime assessment: reconstruction of the crime, crime classification, staging issues, motivation, and crime scene dynamics.[22]

As indicated, crime assessment involves reconstructing the crime. Ressler, in describing the assessment phase, stated:

> The crime assessment stage in generating a criminal profile involves the reconstruction of the *sequence of events* [italics added] and the behavior of both the offender and the victim. Based on the various decisions of the previous stage [the decision process model], this reconstruction of how things happened, how people behaved, and how they planned and organized the encounter provides information about specific characteristics to be generated for the criminal profile.[23]

It is apparent that a viable method of crime scene reconstruction is necessary in order to attempt any type of criminal profile. However, such a technique must be objective. This is true because the reconstruction helps ensure the objectiveness of the profiler, in performing what can only be described as a subjective process. As Turvey himself reported, "forensic analysis is of paramount importance because it helps to preserve the criminal profiler's objectivity by protecting them from investigative assumptions."[24] An integral and unmistakable part of the third step of criminal profiling, crime assessment, is reconstructing the crime in an objective manner. How one achieves objectivity is through the application of scientific method.

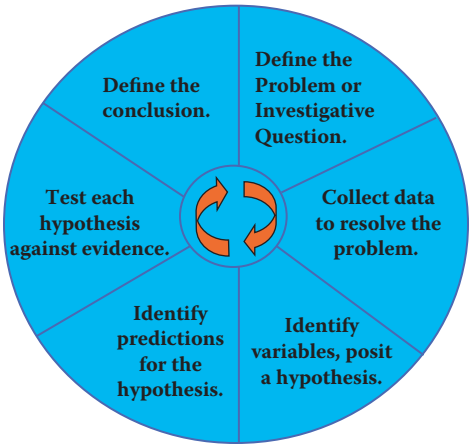

Figure 14.1 Scientific method follows a six-step process that begins with a question and ultimately ends with some answer. However, in a search for true understanding, each new answer usually begs another question. The result of scientific method is an ever-expanding and self-correcting body of knowledge.

The Application of Scientific Method in the Reconstruction Process

As we described in Chapter 4, scientific method is the manner in which humans resolve complex and abstract problems (see Figure 14.1). This is accomplished by asking and answering specific questions and following a defined but hopefully simple methodology. As was the case for bloodstain pattern analysis, crime scene reconstruction must follow scientific method if the analyst hopes to achieve defensible conclusions.

Remember that the data used in crime scene analysis is the physical evidence and its context in the scene. These data elements are objective. If considered properly and within any limits set by associated disciplines, the physical evidence will lead the analyst to valid defined statements about what did or did not occur within the scene. Subjective data is ignored in crime scene analysis; interjecting it weakens the conclusions. The analyst does not simply dismiss subjective data, but he recognizes that the crime scene analysis must be developed independently, and then later considered along with any subjective data. Therefore, testimonial evidence is rarely included as data in a crime scene reconstruction. To apply the tenets of crime scene analysis it is important to understand its underlying theory, the supporting principles, and the questions posed about any item of evidence down to four basic issues. As there are several defined methodologies, the specific methodology used by any given analyst may differ from the next analyst. This chapter will discuss the methodology known as Event Analysis.

Theory and Principles of Crime Scene Analysis

In this day and age one can absolutely count on lawyers attacking even the most basic concept presented before the court. In such an environment, the crime scene analyst must come to court prepared to do battle. To do this demands an understanding of the underlying theory of crime scene analysis as well as the supporting principles used by the analyst. Analysts can expect to be taken to task on the "scientific" aspects of their analysis and

must be capable of articulating these ideas to the court. In 1997, we introduced a simple concept in the first edition of this book, which said: *Nothing just happens*. This statement has always been and remains the basis of all crime scene analysis. Every physical system has components that interact and produce effects. If we know the condition of the system at any one point, then we should be able to predict past and future states of the system to some level. Thus, every action and event that occurs has a set of circumstances that preceded it, and every action and event will ultimately produce some subsequent condition. Call it what you will, but if we simply revisit our archeological correlation, it is nothing less than history. This theory is inviolable; no counsel, no matter how eloquent, can ever prove it wrong. No instance in the oral or recorded history of humans has ever "just happened." Some preceding circumstances existed before any given moment in time, and some set of circumstances or result existed after it. There is no other possibility. This is a basic restatement of the nature of science, associating cause and effect.

This theory that nothing just happens guides and drives everything the crime scene analyst does. Be mindful, however, that as true as the theory is, the crime scene analyst is still limited in his ability to recognize these pre- and post-conditions. The archeologist's dilemma is very much in effect, although it does not alter the theory. For instance, 30 years ago, investigators may have had no capability to recover dust footprints or DNA, but dust prints and DNA were present in the scenes. The theory held true, we simply did not know what to look for or how to capture it. Therefore, the limiting factor in crime scene analysis is the ability to recognize, through the data available, observable cause-and-effect relationships in our scenes. The crime scene analyst will never be able to define and recognize all of them, but those that are evident tell us much about what happened and in what order it happened.

This consideration of the ability to recognize observable cause-and-effect relationships is significant in the application of crime scene analysis to specific case conclusions. In science, a conclusion is only viable if it can be tested. If we consider case specific conclusions about what happened, if there are no observable or testable predictions that will support or refute the conclusion, it is nothing more than an opinion without foundation (whether one wishes to support or refute the specific conclusion).

As an example, consider a situation in which there is a gunshot injury to a victim found in a kneeling position. A significant blood pool developed after the victim bled out, marring all underlying surfaces on the floor. The terminal ballistic information tells us something about the path of the bullet through the victim, but there is no evidence of a subsequent strike. Therefore, we do not know what path the bullet took after exiting the head. Additionally, there are no spatter present in the scene on any surface. If an analyst offers the opinion that the head was down-turned and that the resulting forward spatter were projected onto the floor and are simply beneath the blood pool, as possible as this scenario may be, it is not a valid conclusion. There is no observable or testable prediction that can be used to refute or corroborate the claim. It is based on an assumption that there are spatter beneath the blood pool. In crime scene reconstruction, there must be some observable or testable foundation on which the conclusion is based. Nothing just happens, but we cannot assume the specifics of what happened without a solid foundation (e.g., founded in physical evidence).

Supporting this basic theory of "nothing just happens" are four principles that help us recognize various relationships between our data. One has been an underlying principle of forensics for nearly 80 years: Locard's Principle of Exchange. Two are taken from archeology; they are Nicolas Stenos' Principles of Superposition and Lateral Continuity.

The fourth principle is a shared concept in both crime scene analysis and archeology, the concept of chronology.

Locard's Principle of Exchange

Edmund Locard set forth his Principle of Exchange in the early 1900s. In describing his beliefs, he said:

> The principle is this one. Any action of an individual, and obviously, the violent action constituting a crime, cannot occur without leaving a mark. What is admirable is the variety of these marks. Sometimes they will be prints, sometimes simple traces and sometimes stains.[25]

One can only wonder if Locard himself understood just how correct he was, for as forensic technology advanced so too did the application of his principle. Today it is succinctly stated as: *Every contact leaves its trace*. Every interaction in the crime scene leaves some form of evidence. Fingerprints, DNA, heat signatures, fibers, hairs, soils, and assorted other traces of materials — the list of evidence that may be left behind is nearly endless. Locard's Principle is the basis of all trace evidence examinations; it permeates every area of forensics and serves as the foundation of the forensic linkage triangle (see Figure 14.2). In its typical form, Locard's Principle is applied to the world of trace material, but if one considers it in a larger perspective it is a restatement of our theory that nothing just happens.

Nicolas Steno's Principle of Superposition

Nicolas Steno was a preeminent force in the founding of modern geology and its subdiscipline archeology. He defined basic principles for understanding geologic strata, and those principles have since been carried over to evaluating archeological strata, and associated artifacts. One of these principles was the Law of Superposition. In effect, Steno's

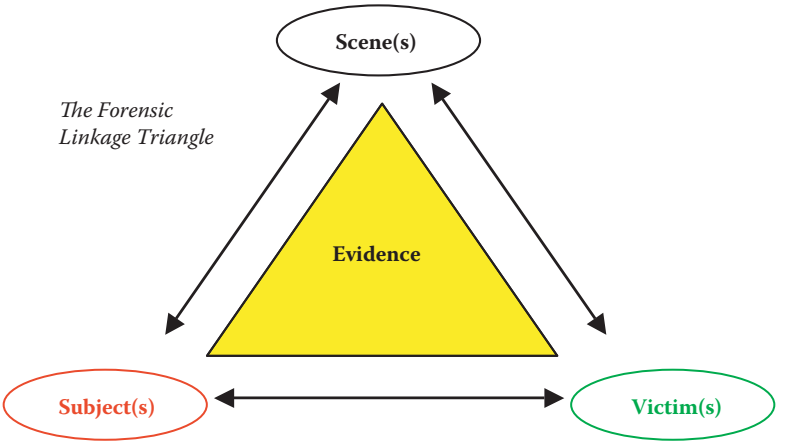

Figure 14.2 The forensic linkage triangle is a basic concept based on Locard's Principle of Exchange.

Figure 14.3 A crime scene example of the application of Steno's Principle of Superposition. In considering the victim's hair, the plastic bottle, cell phone, and purse, it is apparent that the bottle is beneath the hair and the hair is beneath the cell phone. Unless altered in some fashion, this establishes a sequential order for their deposit. Depending upon what we find when we lift the purse, it too may be sequenced in relation to these objects.

Principle of Superposition states that geologic strata (and associated artifacts) are deposited in a time order, oldest to youngest, unless otherwise disturbed. Thus, if three layers of strata and artifacts are uncovered, the one at the bottom is the oldest, and the one in the middle is younger than the bottom layer, but older than the layer above it. Each layer of strata is followed in age by each subsequent overlying stratum. Artifacts in crime scenes are often found in layers. The nature of these layers is not quite geologic strata but they are layers nonetheless. These layers help us put order to events and actions (see Figure 14.3). Of course, as Steno pointed out, our understanding of the sequence of deposit for these layers can always be affected by some subsequent alteration.

Nicolas Steno's Principle of Lateral Continuity

Another of Steno's principles is Lateral Continuity. In part, it states that disassociated but similar strata can be considered from the same depositional period because strata do not simply end. Steno believed geologic strata were continuous for extended areas and did not end abruptly. As applied to excavations, this means that if a layer in a dig contains a similar type of soil and similar artifacts to another layer located nearby, but not in direct association, so long as the similarities are sufficient (nature of the soil, nature of the artifacts) the two layers are considered to be from the same time period. Their disassociation was simply the result of some subsequent geologic alteration. The application of the Principle of Lateral Continuity in simpler terms is a "contextual association." It is applicable to the crime scene but in a less direct manner. Disassociated strata simply are not as common in the crime scene as layering of artifacts, but they do occur in a crime scene context. For example, the recognition of a void pattern in a bloodstain pattern is an application of the lateral continuity mindset. When we encounter a void, we recognize the pattern of blood did not simply stop. Something interrupted it or some portion of the pattern was altered (e.g., removed). A type of disassociated strata/artifact often encountered is spatter (see Figure 14.4). Consider small spatter found on both the weapon and surfaces in the crime scene. If similar spatter are located on a suspect's clothing, as long as the similarities of the spatter are sufficient (e.g., DNA, size and dispersion characteristics) and there is evidence of only one spatter

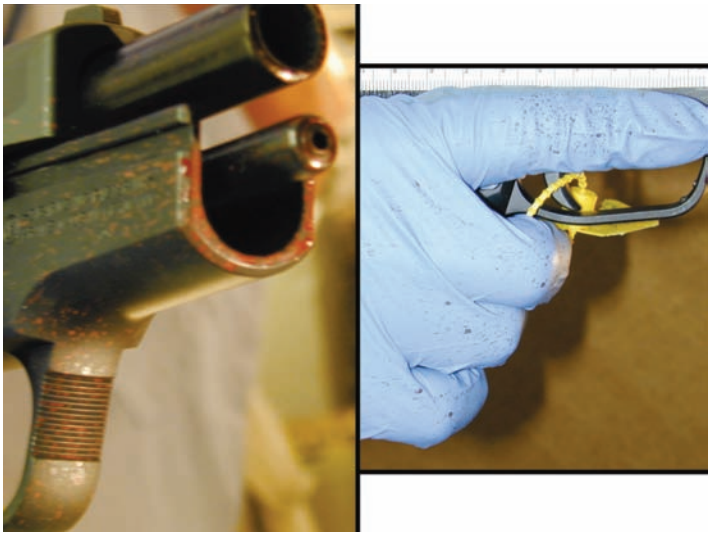

Figure 14.4 A crime scene example suggested by Steno's Principle of Lateral Continuity (contextual association). The event that deposited spatter on the weapon also simultaneously deposited spatter on the gloved hand. If we find these deposits disassociated from one another and sufficient similarities exist (e.g., DNA, size dispersion), then these artifacts can be considered as resulting from a single deposit.

event (e.g., a single gunshot), they represent disassociated strata. However, using this idea of association, they can be considered a result of the same deposit.

Chronology

The last principle of concern is chronology. This is a bedrock concept in archeology, so much so that it has been stated that any discussion of archeological events without consideration of time and sequence is meaningless. In archeology, there are two forms of chronology — absolute and relative. Absolute chronology relates to time, the ability to date an artifact or event through some mechanism or relationship (e.g., a coin stamped with a date). Relative chronology, on the other hand, is the ability to define a relative order to a series of artifacts or events (e.g., the layering of artifacts evident through superposition).

In crime scene analysis, these concepts of chronology are better known as timing and sequencing. Absolute chronology or timing is established through various mechanisms. Video surveillance, 911 calls, patrol car cameras, and other similar devices offer an ability to put a specific time to an event. More classic examples exist in the form of time-of-death determinations by the Medical Examiner or the interruption of daily activities for murder victims. One can never truly predict where timing data will come from, but it is not as common as sequencing information.

Relative chronology or sequencing is the more common evidence encountered in crime scene analysis. It is not concerned with establishing a specific time, but rather with establishing a relative order of events (e.g., Action A preceded Action D, which was before Action F). This information, in conjunction with any known timing data, will provide an overall time and sequence flow. Sequence is established by looking for simple relationships between actions and events. In field archeology, the evaluation of chronology

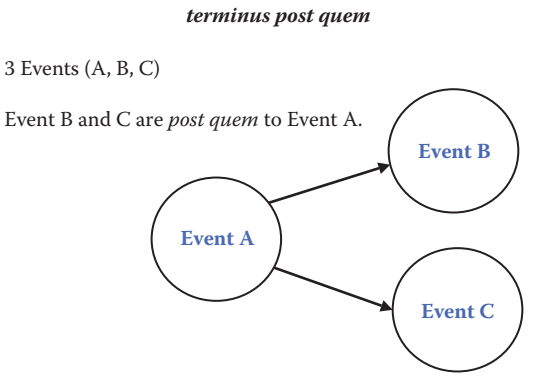

Figure 14.5 The crime scene analyst uses three simple relationships when applying chronology: *terminus post quem, terminus ante quem,* and *terminus peri quem*. *Terminus post quem* means that the event or event segment follows some other event segment.

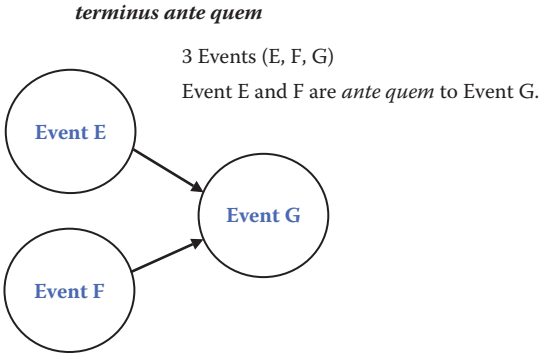

Figure 14.6 *Terminus ante quem* means that the event or event segment precedes some other event segment.

involves establishing two relationships. Either something is *terminus post quem* (a point in time on or after which a feature was deposited) (see Figure 14.5), or it is *terminus ante quem* (a point in time before a feature could have been deposited) (see Figure 14.6). With slight modification, the crime scene analyst applies these relationships to his evaluation of relative chronology. Given the differences between archeology and crime scene analysis, the only modification required is the necessity to add a third relationship, *terminus peri quem*. In crime scene analysis we deal with a far more recent past. Thus, we often encounter actions that are near simultaneous to one another. *Terminus peri quem* describes the relationship between near simultaneous events (see Figure 14.7).

With these three relationships in mind, the crime scene analyst simply evaluates every action or event, seeking to identify any relationship one may hold with any another. For example, in order for a bloodstain transfer to be produced, there must be an exposed blood source that can be transferred. Thus, in the case of a single wounding, all subsequent pattern transfers in the scene are *terminus post quem* to the wounding. Not every action can or will be associated to every other action, so the resulting sequence will not be linear. It will often be convoluted with many branches that describe specific events (see Figure 14.8). By using all of the evident relationships, however, some overall hierarchy of sequence should be possible.

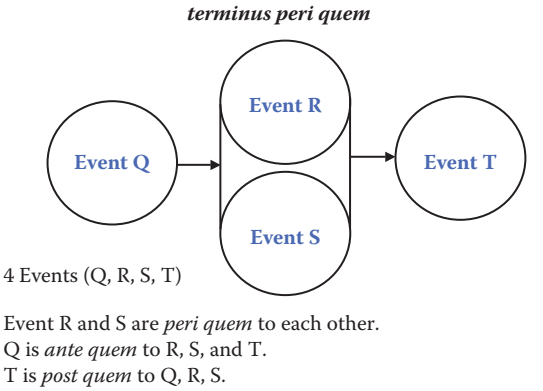

Figure 14.7 *Terminus peri quem* means that in the analyst's eyes the two events are considered to be near-simultaneous.

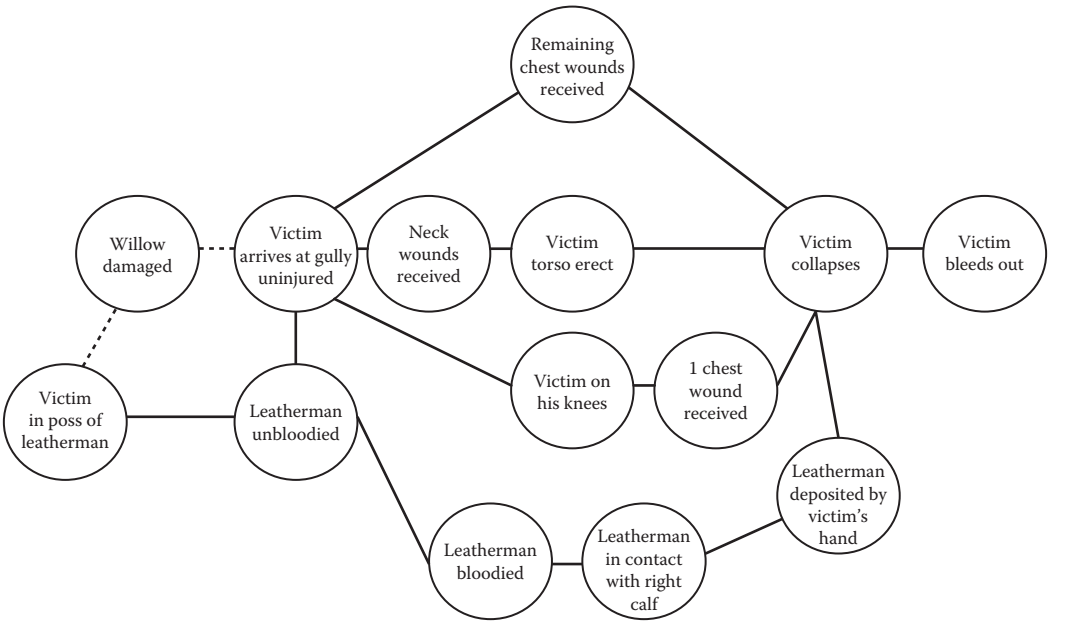

Figure 14.8 A case example of a flow chart. The chart has two specific paths that naturally developed. The upper two-thirds follow the actions of the victim, while the lower third tracks the weapon involved. It is rare that each event segment identified can be directly associated to every other segment producing a "timeline" for the incident. Nevertheless, the connecting lines help describe how the various segments interrelate sequentially.

A Methodology for Crime Scene Analysis — Event Analysis

Event Analysis is a specific methodology that allows the analyst to apply scientific method to the crime scene analysis. It incorporates and applies all of the themes we discovered in prior authors' work, is based on our theory applying the associated principles, and provides a practical approach to reconstructing crime scenes.

In Event Analysis, we will use three terms to define a specific context for the reconstruction. These terms are *incident*, *events,* and *event segments.* The overall crime or occurrence

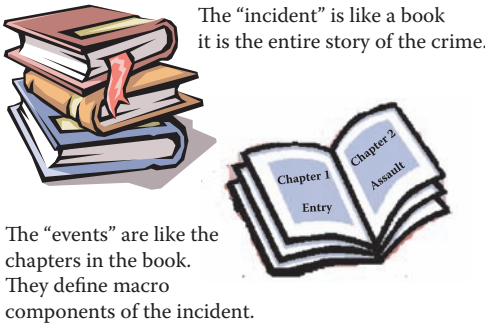

Figure 14.9 Using an analogy of a book, consider the incident as the entire story of the crime being considered. It is made up of many chapters, our events. Each chapter describes a macro-component of the incident.

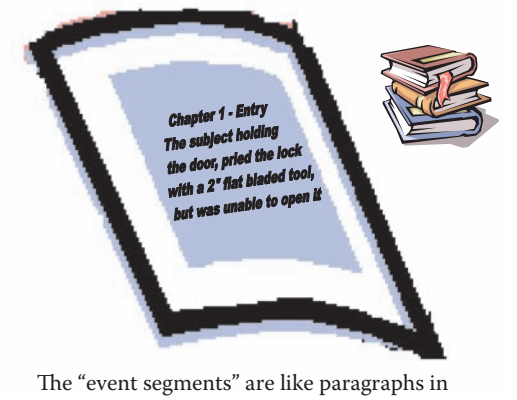

Figure 14.10 Carrying the analogy further, each chapter is made up of paragraphs and sentences containing details that help us understand the story. The event segments are like the paragraphs.

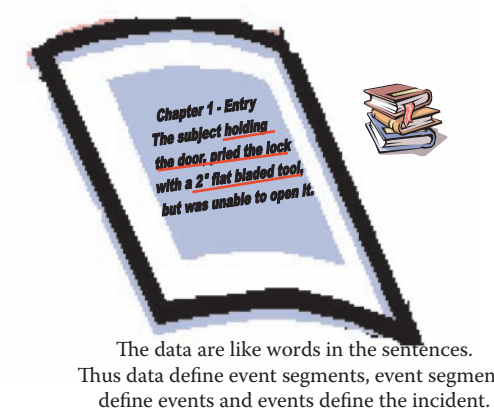

Figure 14.11 Finally, when we look at the detail in the paragraphs, we find specifics (the data) that tell us the story. The more detailed the paragraphs, the more we know about the chapter. The more we know about the chapter, the more we know about the story. In the same way, crime scene data define event segments. Event segments define the event and the events tell us the story of the incident.

in question is the incident. The incident encompasses all actions related to the occurrence. Using a book analogy, it is the overall story of what happened. Within the incident, there are specific events and event segments. Each event describes a major aspect of the occurrence, a macro-component analogous to a chapter within the book (see Figure 14.9). An event is broken down into segments, specific actions taken, which are in turn defined by the presence of specific evidence. Each of these smaller actions is known as an event segment. Using the book analogy, they are like the paragraphs and sentences that make up the chapter (see Figure 14.10 and Figure 14.11). Event segments are time snapshots of the incident; moments and actions defined by some physical form. We know that the event

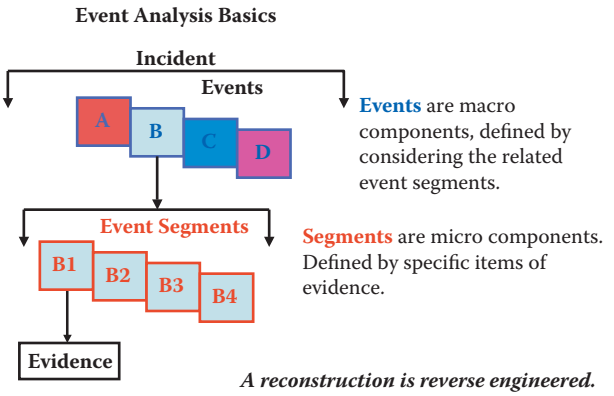

Figure 14.12 A crime scene analysis is reverse engineered. The evidence leads us to event segments. The event segments tell us about the events and together they detail the incident.

segment occurred based on facts and data, some physical manifestation such as artifacts, or a condition from the crime scene.

A crime scene analysis then is reverse engineered (see Figure 14.12). We use evidence and data to define event segments. The more event segments we have, the more we understand the nature of the event. The more fully we can define the events, the more fully we understand the overall incident. Since this reconstruction method attempts to define the crime or incident by establishing these events and event segments, we call the process Event Analysis. The steps taken to create a crime scene reconstruction using Event Analysis are:

- Collect data.
- Establish specific event segments (time snapshots).
- Establish which event segments are related to one another.
- Sequence these related segments, establishing a flow for that event.
- Consider all possible sequences, auditing the evidence when necessary to resolve contradictions.
- Based on the event segment sequence, final order the events themselves.
- Flowchart the entire incident and validate the sequence.

As an example, consider an assault and rape in a home. The incident likely consists of approaching the house, gaining entry, making contact with the victim, assaulting and raping the victim, and subsequent departure. These events are simply large chunks of our time window, chapters in the book. In the initial scene evaluation, we can often surmise specific events or at least recognize that "something" was happening in an area in the scene. The incident encompasses all of these processes or events (see Figure 14.13).

Any event, such as "entry," is composed of individual event segments (more precisely, defined time slots). For example, the rapist may check the door or window in question to see if it is unsecured; then, using a crowbar to break the glass, reach through and unlock the entry and climb through the entry point. Each of these actions results in the creation of items of evidence. Our subsequent discovery and analysis of the evidence at the scene helps us establish that the event segment occurred. Examples of this evidence might be fingerprints on the outer surfaces of the entry point, glass fractures in the pane of glass,

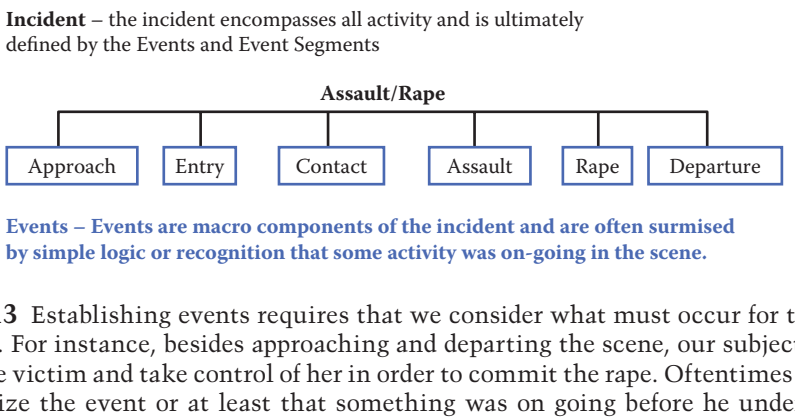

Figure 14.13 Establishing events requires that we consider what must occur for the incident to transpire. For instance, besides approaching and departing the scene, our subject must gain access to the victim and take control of her in order to commit the rape. Oftentimes the analyst will recognize the event or at least that something was on going before he understands the details of what was happening.

glass fragments on the subject's clothes and shoes, and dust footprints or disturbances in the broken glass where the subject stepped.

In seeking to identify event segments, the analyst asks and answers four recurring questions as he looks at the crime scene and the items present in it. The answers to these questions will provide the data used in the analysis. These questions are:

1. What is it?
2. What function did it serve?
3. What interrelationships exist between this item and other items in the scene?
4. What does the item tell us about timing and sequencing?

The first question considers the basic nature of the object. What is it — a gun, a knife or a fingerprint? In the case of obvious objects, this is not a difficult question to answer. Some items, however, may demand significant effort. Examples include fragments (e.g., bullets, paint fragments), trace evidence (e.g., a white powder, accelerants), or simply items unfamiliar to the investigative team.

The second question is concerned with how the item was used. An item may be present in the scene but not used as intended by its design. For example, a bookend may be used as a blunt force weapon or stockings may be used as bindings. Not all functional aspects are obvious on first inspection, but the analyst remains constantly aware of such issues.

The third question looks at interrelationships between articles in the scene. The answer to this question may assist in resolving our understanding of the first two questions. For example, a small metal fragment may be found to be consistent with a deformed bullet, or a liquid at the scene may be identified as fuel consistent with fuel found in a gas can at the scene. Other relationships are also important as well. For example, recognizing a cast-off pattern rising from an impact spatter pattern may aid the analyst in understanding the positioning of parties during the attack; or consideration of a trajectory along with the Medical Examiner's analysis of the wound may aid in placing the victim in a specific position at the time of wounding. There is no limit to the nature of the interrelationships between objects that are of concern to the analyst.

The last question deals with the issue of chronology. What does this item tell the analyst about sequencing different actions or in placing an action at a specific point in time? Examples might include the presence of spatter overlaying a shoe mark or the deposition of

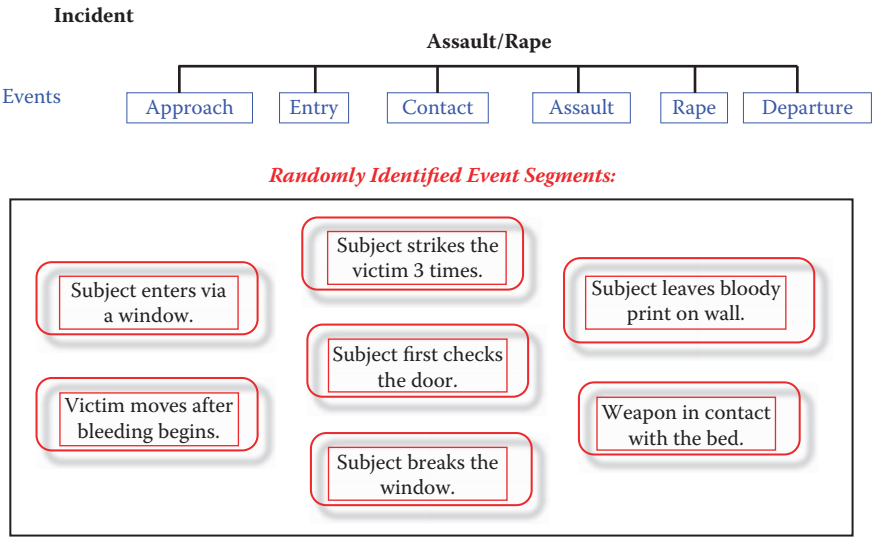

Figure 14.14 Event segments are "snapshots" of the crime. They detail specific actions and are based on our evaluation of specific items of evidence. Initially we may only know that they occurred, without understanding their sequence or relationship to the events themselves.

ceiling debris in an arson scene on top of a victim with no underlying burns. Sequencing information is scattered throughout the crime scene and it is critical evidence.

By asking and answering these questions, event segments from the evidence are defined in no particular order (see Figure 14.14). Each segment is considered against the others looking for association and relationship. Based upon these relationships, the various segments we believe are associated will begin to provide an understanding of that event (see Figure 14.15). Our function now is to order, if possible, these related event segments. This ordering gives structure to how the event transpired. Again, all known information must be considered to place these segments in a logical and supportable order. Using the three relationships of chronology, each event segment is considered against every other event segment. Typically, obvious beginning and ending event segments are found. Other segments may fit together in a very logical and functional order. There may also be segments that appear to fit the sequence loosely, but perhaps we are uncomfortable as to their exact sequence. We are also likely to encounter segments that we believe are related to the event, but for which we do not understand the sequence or order in any fashion. Consider the "Subject Touches Wall" segment in Figure 14.15. We know it happened, but we do not understand when it happened. As simple as it may sound, keep in mind that sequencing is not easy (see Figure 14.16). Nevertheless, using the three chronology relationships we allow an objective order for segments to develop (see Figure 14.17) and then graph the information into a flow chart as in Figure 14.18.

The event flow chart seeks to allow us to graphically visualize the reconstruction. As each relationship is defined, it is graphically depicted. This graphic representation is important. Often the analyst will not recognize a logical flaw in the reconstruction sequence until it is depicted graphically, particularly in complex events. Once drawn out, these flaws are much more evident and easier to recognize. As one might imagine, the analyst will go through numerous iterations of the flow chart as he works through sequencing issues.

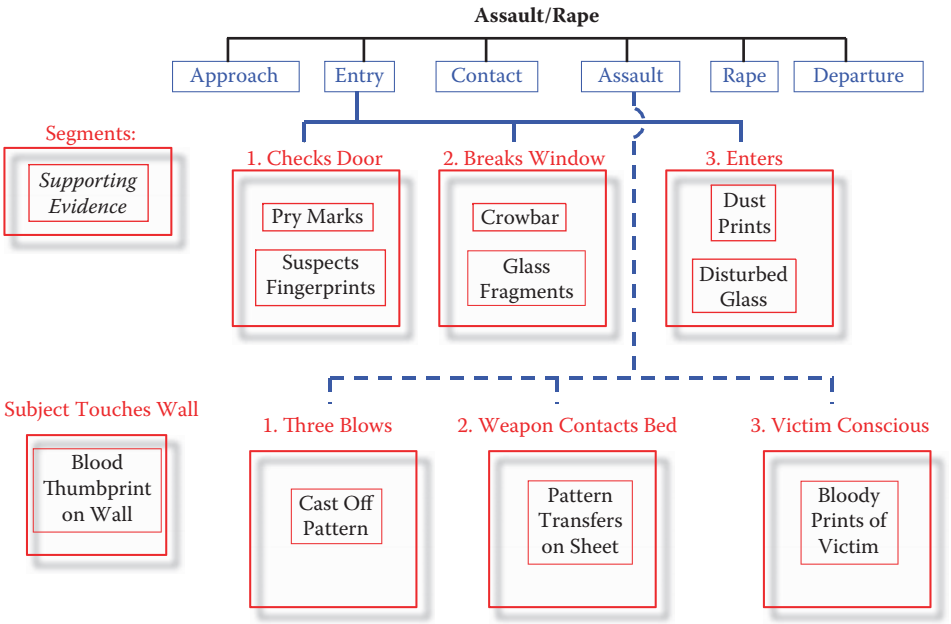

Figure 14.15 In time, we seek to relate the event segments to a specific event and then sequence them. This gives us a clearer picture as to how the incident transpired. Not every segment will have a clear position in the reconstruction. For example, the segment related to the subject touching the wall might well belong to the assault, rape, or departure event; unfortunately, there is insufficient evidence to establish where it belongs in the overall reconstruction.

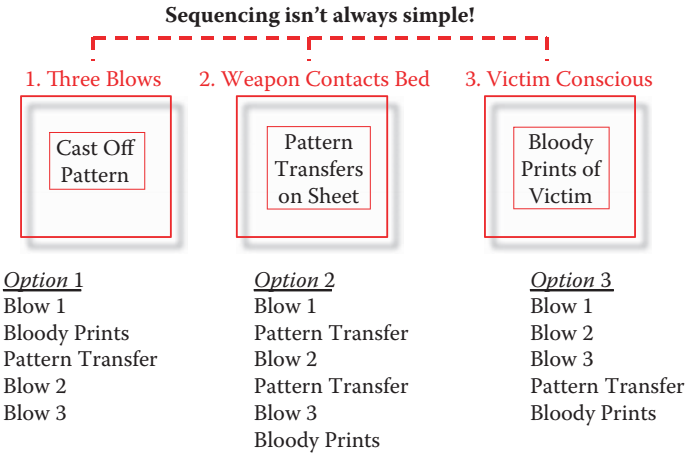

Figure 14.16 Sequencing, although easy enough to understand, is not always simple. We may be presented with a series of event segments with little sequencing information available, or a number of permutations in how the sequence may have transpired.

Remember that every event or event segment has some action that leads to or follows it. Nothing just happens. There is no "Beam me up, Scotty" as in Star Trek; our players must arrive, act, and then depart. Consider, for example, the assault segment of "break glass" with crowbar. Refer back to Figure 14.15. In order to break the glass with a crowbar, our rapist must first procure one. In order to procure one, he must either find it on scene or

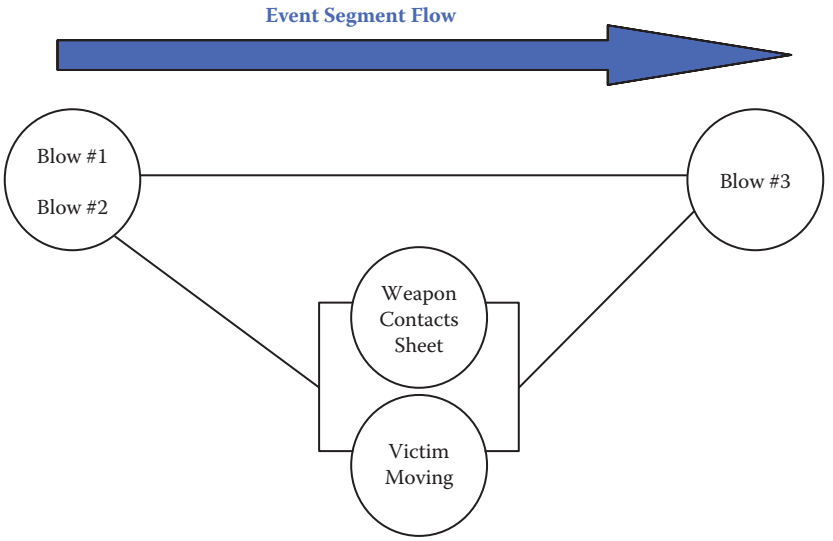

Figure 14.17 Sequencing may not always be simple, but it will ultimately lead the analyst to some conclusion. To get there, the analyst must apply the three basic chronology relationships: something preceded, something followed, or something was simultaneous to some other event segment. As they tie one event to another, a structure will begin to form.

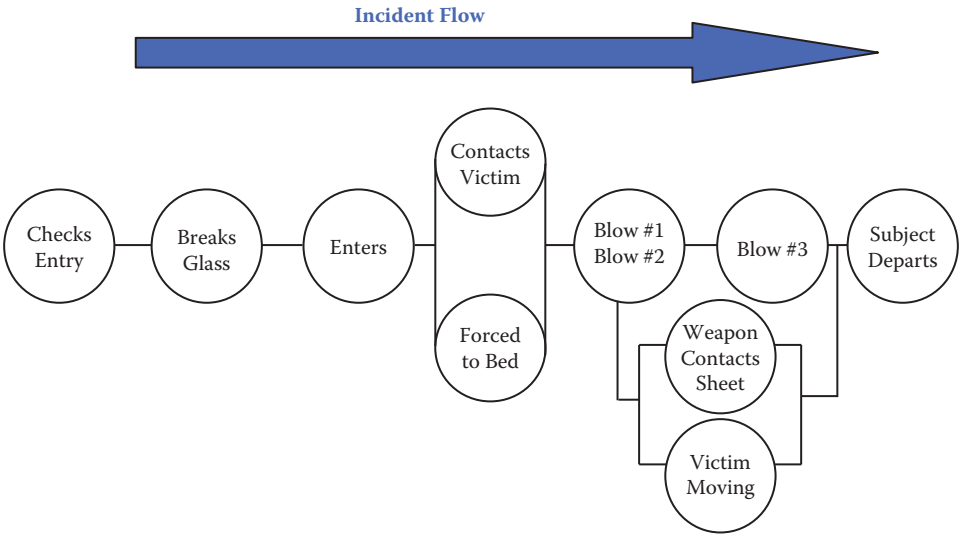

Figure 14.18 Event flow-charting. Using the structure that developed between individual event segments, all of the event segments are tied together in a flowchart model. The application of the chronology relationships provides an objective and supportable sequence. In effect, the flowchart is a graphic representation of the reconstruction.

bring it with him. If found on scene, it must have existed there previously for some reason, or have been brought by someone else. If brought by the rapist, he must have brought it from somewhere. Everything has a history. Obviously, these issues become convoluted and lose relevance to the investigation as a whole; but if for some reason the issue were important, background evidence might well exist to prove its occurrence. This leads us to auditing.

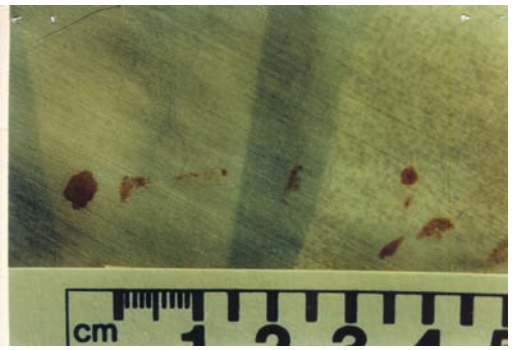

Figure 14.19 This pattern transfer on a pillow in a room disassociated from the homicide presents an auditing situation. Several possible event sequences or scenarios may explain it. The analyst is left to decide if any of these possibilities can be eliminated in order to bring more clarity to the situation.

Oftentimes the investigation will present the analyst with contradictory evidence that supports two or more possible events or event segment sequences. By looking at this background evidence, we can audit the evidence in order to help establish which of the events or sequences is the more viable answer.

Consider an example of auditing. Imagine a situation in which we have two possible locations in a scene for a shooting. Based on examination of the evidence present, either location could conceivably be the location. Testimony by the defendant indicates the shooting occurred at the first location (a small bathroom). He claims he placed the weapon on the floor there and never again moved it. This information supports his overall claims. The barrel of the weapon was bloodied by contact with the victim when it was fired. We also find a bloody pattern transfer consistent with the weapon on a pillow at the second location of interest (see Figure 14.19). In considering the pillow and pattern transfer in relation to the defendant's claim, it is possible that:

- Previously the pillow was at the location claimed by the defendant, it made contact with the weapon, and was later moved by someone.
- The shooting occurred where the defendant claimed, the weapon was moved, came in contact with the pillow, and was then returned to the original site.
- The shooting occurred at the second site, where the weapon made contact with the pillow, the weapon was then returned to the first location, which was staged to look like the shooting scene.

The analyst's issue becomes one of finding some means of deciding which of these possible explanations is correct. In examining the pattern transfer we are confident the weapon caused it. The pillow exhibits no other stains. We also find that at the first location, where the defendant claims the shooting occurred, watered-down stains are present from another event. These watered-down stains appear to be related to the splashing of bloody water in the tub. The subject is adamant that these occurred just before the shooting and relate to another minor injury. These stains are evident on all surfaces and objects present near the first location.

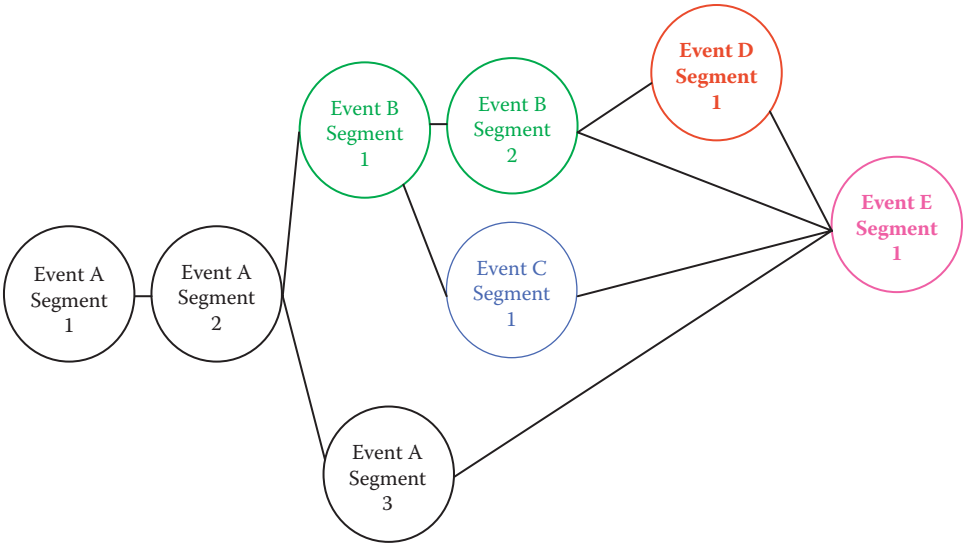

Figure 14.20 In this example, there are five events (A–E). Various segments of one event have a sequential relationship to another event's segments. This crossover information allows the analyst to objectively put the events in some order as well.

Given the presence of these splash stains all around the bathtub and the lack of similar stains on the pillow, it is obvious the pillow was not subjected to this event. If the subject is being truthful and the first location is the site of the shooting, then the splash event occurred, causing the stains on the walls and surfaces, the pillow was then moved to this location, the shooting occurred, the weapon came in contact with it, and the pillow was removed and replaced in the second location. Unfortunately, he neither claims this, nor in his overall description had sufficient time to take such action. This excludes the pillow's presence at the first location before the shooting. The remaining explanations are: The weapon was moved from the first location, came in contact with the pillow at the second location, and was then returned, or the second location is the actual site of the shooting.

Although auditing does not answer absolutely which explanation is *the* explanation, it eliminates one possibility, establishes that the defendant's story, as told, is not completely accurate, and certainly points us back to the second location. In this instance, the watered-down stains, which did not relate directly to the shooting event, provide a means of discriminating between the various possibilities for the shooting. Auditing can be an extremely effective tool for reconstruction, but it demands that we look beyond the immediate issues.

Sequencing and flowcharting begin in the fourth step of Event Analysis and continue throughout the reconstruction effort. The sequence developed through individual event segment relationships and auditing will ultimately provide structure to the relationships between the events as well. As we develop an understanding of the event segment sequence, the result often provides crossover relational data between events. An event segment related to one event may have a sequential relationship to an event segment associated with another event (see Figure 14.20). For example, the rapist may become bloodied in the altercation, then subsequently leave bloody swipes on drawers when rifling through the home. This information allows the analyst not only to recognize the additional event (rifling of the home) but to validate the sequence of one event to another.

In most instances, the order of the events develops by logically considering the event segments in and of themselves, but occasionally there may be lingering issues. For instance, in our example of the burglary/rape, the investigative team's initial assessment may suggest that entry was made followed by rifling of the house, and it was then that the homeowner was raped. However, the relationships established between the event segments in Step 4 are more objective than any initial beliefs, so if there is a contradiction between the initial assessment and the formal analysis it will demand revising the initial beliefs. The presence of the victim's blood on the objects rifled in the scene forces a sequential relationship that demands revising the initial hypothesis.

Once the overall analysis is complete, the analyst must return to his flowchart and validate it. This requires the analyst to question each sequence demonstrated on the flowchart and to look for unrecognized relationships. Once this task is complete, a final form of the flowchart is produced and the reconstruction is complete; that is, unless additional information is forthcoming. In that instance, the additional data must be examined and considered in an effort to see if it better defines the overall sequence, or if it suggests that the analyst has incorporated some as yet unrecognized logical error.

Putting the Pieces Together

The limitation in the reconstruction task should be evident; the analyst seeks to look back in time. In many instances, there is no one, beyond the subject, who can provide details regarding what occurred. Even in situations where eyewitnesses exist, the seasoned investigator realizes that witnesses often give conflicting testimony for various reasons. In the end, proper analysis of physical evidence shoulders the greatest burden of proof in establishing these past events.

Often, when presented with less than clear circumstances, investigators depart from objective concerns and turn to subjective issues. Statements like "That's not logical, why would he do that?" begin to appear. It is not that we are not concerned with motive or intent, but once we stray to subjective issues in order to define our crime we lose touch with our most authoritative asset. Perhaps Herbert MacDonell put it best in the title of his book, *The Evidence Never Lies*. We can best define our incident by considering the physical evidence in a clear and objective manner. From this solid platform, we may always reach out to explore the more subjective concerns.

Given the dynamic nature of our world and its interactions, no one can establish every action related to crime with certainty. Paraphrasing Voltaire, only a charlatan is absolutely certain of everything. We must follow a proven path of evaluating the evidence and context present in the scene, using scientific method, and applying formal Event Analysis whenever possible. To accomplish this, the crime scene analyst must refine his context of observation which is done by "assess[ing] the entire scene, noting all competing explanations [and] refusing to be guided by inappropriate preconceived expectations."[26]

By understanding the underlying theory and principles of reconstruction and applying a practical methodology that objectively moves the reconstruction effort forward, the analyst can define specific actions that occurred and the likely order of those actions. Event Analysis is such a methodology, incorporating the long-standing themes of crime scene analysis. Using Event Analysis, the incident in question begins to emerge as a series of objective moments, which we then link and sequence to produce the best explanation of

the events that encompass the incident. Once defined in this fashion, we may always turn to the more subjective issues and, using sound reasoning skills, attempt to define the "why" of the crime.

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Presenting Evidence

15

Preparation for court begins long before any actual court date. Having failed to prepare properly, analysts should not be surprised when a skillful attorney cuts them to shreds on the witness stand. After such a mauling, and usually while nursing a bruised ego, the analyst is likely to blame the situation on "that unmerciful attorney." However, if we step into the witness chair unprepared or oblivious to the nature of the court, then perhaps we deserve such treatment. The culmination of any analysis is to demonstrate in court the conclusions drawn from the analysis. In meeting that end, the analyst can never take preparation for trial lightly.

One of the more important aspects of presenting evidence as an expert is in understanding and meeting the expectations of the court. This involves explaining the nature of the discipline involved and the background of the expert.

Understanding the Nature and Content of Daubert or Similar Challenges

Before an analyst testifies in front of a jury, he often undergoes an admissibility hearing referred to as a *voir dire*. In this hearing, the opposing attorney will question the witness on several areas to include the following:

- The expert's qualifications in the area he is being proffered as an expert (e.g., the expert's training, education, and experience in bloodstain pattern analysis)
- The nature of the bloodstain pattern analysis
- The accepted methodology and if the methodology was followed in this case
- Additionally the analyst may be asked to provide the court with documentation of recent cases in which the expert testified

In preparing himself for such a challenge, the analyst should become familiar with which standard the jurisdiction uses as the benchmark for the admissibility hearing. Countries outside of the U.S. will likely have their own rules and these may not even remotely follow U.S. rules; however, a review of the following standards may serve as preparation for analysts from other countries. In U.S. federal court the Federal Rules of Evidence apply (e.g., Rule 702), whereas U.S. state courts may follow any number of different *voir dire* standards, including Rule 702, Frye, Daubert, or Kumho. Each of these legal opinions defines a specific standard for expert opinion and, in essence, challenges not only the expert but also the discipline itself. There is overlap between each; however, the analyst should be thoroughly familiar with the one used by the jurisdiction in which he is expected to qualify.

Daubert v. Merrell Dow Pharmaceuticals, 113 S.Ct. 2786 (1993)

A Daubert challenge is one of the more common forms of challenge. It includes questions on the following:

1. Has the discipline/methodology been tested?
2. Has the discipline/methodology been subjected to peer review and publication?
3. Is there a known or potential error rate for the discipline?
4. Has the methodology been accepted by the relevant scientific community?

Frye v. United States, 293 F. 1013 (D.C. Cir. 1923)

A Frye hearing includes questions on the following:

1. Will the expert testimony assist the jury in understanding the case?
2. Is the testimony based on scientific principles that are accepted in the discipline?
3. Is the witness qualified in this discipline?
4. Is the witness credible?

U.S. Federal Rule 702

A challenge based on U.S. Federal Rule 702 will include questions on the following:

1. Is the testimony based upon scientific testing?
2. Is the testimony based upon scientific principles and methods?
3. Did the witness apply the scientific principles and methods reliably to this case?

Responding to *Daubert* or Similar Challenges

In order to meet and prevail during a *voir dire* challenge, the analyst must be prepared to answer any of the questions posed by the specific challenge. The best way to plan for and respond to a challenge is to build predicate questions. The most basic form of these predicate questions is as follows.

What Is Bloodstain Pattern Analysis?

The analyst must be able to explain to the judge and jury in his or her own words what bloodstain pattern analysis is. At a minimum, the answer should probably include the following descriptions and definitions:

- What is liquid blood?
- What physical laws and principles apply in bloodstain pattern analysis?
- What actions or events can a study of the bloodstain's physical characteristics identify?

- How is the analysis accomplished and what accepted methodology was utilized? (Refer to Chapter 4 for methodology discussion.)

What Is the Purpose of a Bloodstain Pattern Analysis?

In his or her own words, the analyst must explain to the jury what an analysis might identify, including:

- Identifying specific bloodshed events that occurred
- Identifying the location of the attacker and the victim during bloodshed events
- Identifying the sequence of different blood spatter events
- Identifying movement of people and objects in the scene

The analyst should also explain that the analysis is used as a benchmark against which to consider what witnesses, suspects, or victims have stated.

What Principles Apply to Bloodstain Pattern Analysis?

In his or her own words, the analyst should explain how basic principles of mathematics, biology, and physics are used in an analysis. He or she should describe how force, velocity, surface tension, molecular attraction, and cohesive or disruptive forces affect the patterns as found.

What Is the Methodology Used in Bloodstain Pattern Analysis?

In his or her own words, the analyst should explain the specific methodology he or she used in completing the analysis. Areas of interest include:

- In general, that analysis includes gathering information, correlation of data collected using observational skills, and how specific information and evidence was documented
- How the scientific method was implemented in order to accomplish the analysis
- The limits of any conclusion provided should be fully explained, including the fact that bloodstain pattern analysis is a class characteristic evidence
- If methods such as technical or peer reviewed were used, they should be explained, and if not utilized, the analyst should explain why they were not employed

Where Has Blood Pattern Analysis Been Accepted in Judicial Settings and within the Scientific Community?

In his or her own words, the analyst should explain to a court where bloodstain pattern analysis has been accepted by the courts and scientific community.

- The analyst should articulate that bloodstain pattern analysis as a discipline predates the majority of forensic disciplines.
- In its modern form it has been accepted throughout the U.S. in municipal, county, state, and federal courts, as well as in many different countries including the United Kingdom, the Netherlands, Canada, New Zealand, Australia, Korea, and others.

What Scientific Studies Have Been Published in Peer Review Journals?

In his or her own words, the analyst should be prepared to identify for the court some of the textbooks and studies addressing the scientific validity of bloodstain pattern analysis.

Are There Professional Associations That Recognize Bloodstain Pattern Analysis?

The analyst should be prepared to identify the many professional associations involved in bloodstain pattern analysis including: the International Association of Bloodstain Pattern Analysts, the International Association for Identification, the Association for Crime Scene Reconstruction, the American Academy of Forensic Sciences, and the Scientific Working Group on Bloodstain Pattern Analysis.

Is There an Identified Error Rate for Bloodstain Pattern Analysis?

This is one of the more difficult questions the analyst will encounter. In his or her own words, the analyst should explain that there is no known error rate associated with the methodology of bloodstain pattern analysis. There are, of course, error rates associated with specific skills and tasks associated with the discipline. These include the error rates associated with impact angle determinations and area of origin determinations.

Ultimately, by considering these predicate questions and being prepared to functionally articulate answers for each, the analyst will meet any *voir dire* challenge he or she might encounter. Keep in mind that effectively articulating these answers is important. Just knowing the answer will not do the analyst any good. He or she must be prepared to explain the answer under stress in a contentious arena (i.e., the courtroom) against an adversary who is bent on confusing and preventing the answers from coming out.

General Concerns for Testifying

Analysts should investigate and prepare reports in every case with an eye on the witness stand. Their own report can often come back to haunt them, so it must not contain inaccuracies, discrepancies, exaggerations, or unsupported theories. When writing the report the analyst must keep the following questions in mind: How can I substantiate this in court? What is the foundation of this conclusion?

When presenting an opinion to the court, be prepared to use demonstrative evidence, such as large photographs or charts, as a method of educating the jury. As discussed previously, computer resources are also helpful in this regard. They can effectively illustrate specific events and points related to the analyst's testimony.

The ability of the analyst as an instructor is a concern that cannot be overemphasized. An expert opinion that the jury fails to understand is a worthless opinion. Conversely, if a conclusion is clear, logical, concise, and understood, the jury is likely to find such testimony extremely valuable. Therefore, analysts should use all appropriate illustrations to let the jury "see" and not simply hear their testimony.

Maintaining Objectivity

It is important to maintain objectivity throughout the trial. Remember, the analyst's role is that of a witness, not an advocate. It is not their job to help an attorney win the case, and such an attitude often leads analysts to include unsubstantiated details in their conclusions. The jury will view this behavior as a bias or prejudice, and rightfully so. In the end, it can destroy the analyst's overall credibility.

Nevertheless, pressures to be "one of the team" will be present. Police organizations employ many bloodstain analysts directly within the structure of the agency. As such, it is easy to identify singularly with the goals of the investigation. Additionally, the analyst may team up with the prosecutor, building the particular case against the defendant. In the process, the analyst is subjected to the "Us and Them" attitude found in the adversarial court system.

It takes a conscious effort by the analyst to remain impartial, but bloodstain pattern analysis demands this impartiality. This might seem at odds with our purpose, as certainly the analyst will eventually conclude that something happened. Being adamant in the conclusion is not a bad thing, but the analyst becomes adamant only by evaluating all evidence and considering all possibilities. The analyst's conclusion objectively recognizes inherent strengths and weaknesses. This kind of impartiality is very different from pursuing only that evidence which supports a specific theory. Impartiality demands we recognize the difference between the two and pursue the holistic approach.

An important recognition on the analyst's part with regard to any conclusion is that the nature of conclusions are different. Certain conclusions may be arrived at deductively; thus, their certainty is much higher. On the other hand, certain conclusions may be arrived at inductively; thus, it is the best explanation given the data, but by no means absolute. The best example of this difference in bloodstain pattern analysis is the difference between classification and identifying a source event. If the analyst understands and follows a deductive classification process (as explained in Chapter 3), the classification conclusion arrived at (e.g., this stain is an impact spatter pattern) for most bloodstains should not be in question. On the other hand, identifying a specific source event (e.g., this impact spatter pattern was produced by a gunshot) for the same pattern is not always as certain. Such a conclusion generally involves some form of inductive argument and thus may be open to some level of interpretation. It is imperative that the analyst know the difference in his conclusions and not oversell any part of his analysis.

Analysts often find the legal system intimidating because it has its own unique purpose and values, and even its own logic.[1] The search for truth in the context of the law is

simply part of the process by which the goal, "justice," is sought. On the other hand, in analysis, truth is the goal. All the analyst is concerned with is being confident that he has identified the best explanation without overstating his conclusion, and has done so based upon all of the evidence available. Of course, the court works in a slightly different fashion. As Peterson explained, "The principle objectives of the litigants is to win the case, often at the expense of truth… counsel tries to extract a slanted picture from the witness, and, on cross-examination, opposing counsel seeks to slant the picture the other way."[2]

As Alan Dershowitz, one of O.J. Simpson's defense attorneys, commented, "A criminal trial is anything but a pure search for truth. When defense attorneys represent guilty clients … their responsibility is to try by all legal and ethical means, to prevent the truth about their client's guilt from emerging."[3] Truth, then, is very often the unfortunate victim of this wrangling, but analysts can ill afford to play this game. They must present their knowledge factually and objectively, no matter how it may be used. If by answering a counselor's question they harm their own position or conclusion, then so be it. Truth is truth, the jury or judge is who must decide if they believe a conclusion. The analyst simply gives them knowledge on which to base that decision.

Analysts can never allow themselves to forfeit their own or their department's integrity. No matter how perturbing the judicial system may be, no matter how adamant their belief in the guilt of some particular subject, they can only report what they know. In the recent past there have been unfortunate cases in which forensic experts, to support a particular position, modified or manufactured evidence. There is absolutely no room in forensics for this type of activity. The analyst owns his integrity; no one can take it from him. To lose it, you have to make a conscious decision to give it away. Guard your integrity carefully, for every time you take the witness stand both the court and society are relying on it. Remember, too, that your testimony must never invade the purview of the jury. The analyst is not there to define innocence or guilt; this task belongs solely to the jury.

Settling in and Establishing a First Impression

Often, it is the first few moments in the witness stand that are the most disconcerting. Unfortunately, these are the same moments when the jury members are defining their first impressions of the analyst. The following actions may assist the analyst in establishing a more positive image.

In preparation for *voir dire* and subsequent testimony, the analyst may wish to assist counsel in preparing qualifying questions. Since analysts know their own qualifications better than anyone else does, they can create questions that place them in a positive light. Of course, it is imperative that the analyst not embellish his credentials in any fashion. Areas to be covered by these questions include:

- Training and years in the discipline
- Position in and years with a given agency
- Articles published or studies conducted
- Schools taught on the subject
- The number of times previously qualified as an expert witness
- Membership in professional organizations related to the field

Preparing these questions in advance and providing them to the appropriate attorney ensures two things: (1) the analyst knows what the questions are and knows how best to answer them, and (2) by knowing the nature of the initial questions, the analyst can relax somewhat and will become more comfortable on the stand.

A relaxed attitude is critical because the jury is evaluating both the analyst's appearance and demeanor. The court's first impression of the analyst may set the tone for acceptance of the entire testimony. To address this issue the analyst should always dress conservatively, preferably in a business suit. Do not wear items such as sunglasses, or anything that might be considered flashy. This has a way of stealing the jury's attention from testimony. If possible, do not testify in a police uniform, as the jury may perceive this as demonstrating partiality to the prosecution.

Demeanor is difficult to maintain and the analyst constantly walks the "demeanor tightrope." One cannot be "cocky," but just the same, one should not be viewed as "timid." Analysts must appear confident in their knowledge, experience, and conclusions. By acting like professionals on the stand, hopefully the jury will perceive them as professionals.

To present this professional appearance, analysts must use every action in the courtroom to their advantage. As they walk into the courtroom, all eyes are on them. Analysts should walk in with their heads up and shoulders back. When taking the oath, they should stand at a position of attention. Their affirmation should be in a voice that is confident and loud enough that a jury can hear them. The actions and manner of the analyst must say, "I am here to be honest and to tell the truth." If done well, the jury's initial impression of the analyst is that of a serious professional.

Attacks on analysts come in a variety of ways, but quite often counselors simply set the stage and allow analysts to impeach themselves. Trained to bring out any attitude of animosity or bias, the opposing attorneys will seek to do so during cross-examination. If this can be accomplished, the attorneys can feel more confident in their own argument knowing that the jury's opinion of the analyst is diminished. If the analyst refuses to be drawn into such encounters and remains objective and calm, then the jury is unlikely to view the analyst in a derogatory manner.

Remember, objectivity and impartiality are critical. If questioned about a weakness in the case, admit it. It is not the analyst's job to convict, but rather to give whatever testimony can honestly be given and nothing more. The analyst's credibility will suffer if there is any attempt to hide a weakness or subjectively dismiss it.

When responding to questions that require short answers such as "yes" and "no," look at the attorney asking the questions. Do not look back and forth from the attorney to the jury during a series of such questions. The jury may find the motion of the analyst disconcerting. On longer answers, the analyst should look at the jurors. In doing so, the analyst builds rapport and further establishes an image of credibility for the court and jury. The analyst should not forget to look back at the attorney, particularly when listening to the questions being asked.

One often observes that even the most experienced witnesses will eagerly answer the questions of their own attorney, and then become immediately defensive or hostile when the opposing attorney asks questions. No matter how aggressive an attorney becomes, the analyst should never get mad or display hostility. If the analyst simply ignores this aggressiveness and continues to answer with confidence, the jury will tend to view the analyst in a more credible light.

Understanding Cross-Examination

For those unfamiliar with court, it is often difficult to understand that a trial has little if any relationship to the investigative process. In the lawyers' mindset, truth has only a limited place in the court. This is best understood by referring to the texts that lawyers use to teach other lawyers about science. Contained within one such text is what we like to refer to as the *Smorgasbord Theory of Science*. The following excerpt very effectively explains the underpinnings of the legal profession's mindset.

Subordination of "Scientific Truth" to "Legal Truth"

> Forensic scientists recognize that they are but the hired help, and that forensic science is but the handmaiden of the legal system. The validity of facts testified to in a court of law by non-expert witnesses is perpetually subject to challenge. When facts are introduced into a court of law by a scientist, however, they are subject to the same challenge. Scientific "truths" are established when the validity of a proposition is proven to the satisfaction of a prudent and rational mind. Legal "truths" are not established by the exercise of the scientific method, but by the processes of the adversary system.
>
> The role of physical evidence in the administration of justice may reasonably be described as follows: Science offers a window through which the law may view the technological advances of our age. Science spreads out a smorgasbord of (hopefully) valid facts and, having proudly displayed its wares, stands back. The law now picks out those morsels that appear most attractive to it, applying selection criteria that may or may not have anything to do with science.[4]

It is important to note that this text is by no means some obscure manuscript. It was penned by four prominent law professors and serves as the basis of teaching other lawyers about science and experts. It is clear and apparent that the legal system as a whole has simply forgotten that truth is truth; in order for a legal truth or, more aptly, a legal opinion (for that is exactly what it is) to be valid it must be based on scientific truths. Logically it cannot be otherwise. More important to this issue and conveniently forgotten by the legal profession is that arriving at "truth" of any nature demands consideration of all information and evidence. To base an opinion on only part of the evidence available is the very definition of ignorance. Certainly, if we as analysts fail to consider all evidence, lawyers and judges are quick to chastise and demean us for our failure, yet the phrase "picks out those morsels that appear most attractive" tells the story of the law profession. Lawyers are trained to start with a conclusion and work backward, picking and choosing those facts that support their claim; all others are simply deemed unworthy. This is not the mindset of any particular group of lawyers (i.e., only defense); it is the mindset of the legal profession.

Thus, what actually does count in court is the manner in which each opposing counsel is able to turn the facts to support his or her own position. For that reason, the analyst must understand and be prepared for the rigors of cross-examination. Counselors use cross-examination to meet a number of objectives, which may include:

- Discrediting the witness
- Discrediting the discipline or methods used
- Discrediting the conclusions or opinions given by the expert

Direct questioning in the initial stages of a trial is like a walk in the park when compared with the antagonistic manner evident in cross-examination. In preparation for this ordeal, analysts must read and know their report. They should review all related reports and any articles or books that have a bearing on the conclusions drawn. Additionally, analysts should know or be cognizant of concepts or theories of other authors that might be counter to their own. Finally, analysts must be able to verbalize under adverse conditions why they reached the conclusion they did.

During cross-examination, expect the opposing attorney to dwell on those areas for which the analyst is not qualified. An example may be the attorney who asks if the analyst has a degree in physics, math, or biology. Often, the attorney will attempt to make the analyst answer simple questions, those to which the analyst may know the answer. Using these answers, the attorney will then try to further the impression that the analyst is claiming to be an expert in that area. During cross-examination, these easy little questions have an ugly habit of turning into a big complex question that ultimately leaves the analyst embarrassed. For example, in bloodstain pattern analysis, even though the analyst is not a serologist, a serology question will likely be asked. The analyst's best response is to state a lack of qualification in the area and request the attorney ask the question of someone who is qualified. If others should answer the question, then let them!

The analyst should never consent to conducting examinations of "new evidence" on the witness stand. It should be evident to the reader by now that analysis demands proper examination in an appropriate setting, with sufficient work space, lighting, magnification, equipment, and time. Off the cuff examinations are exactly that — off the cuff. They have no place in the ultimate analysis, and they certainly do not belong in court.

An associated ploy is to hand the analyst a reproduction from some book, manual, experiment, or case and then ask if the analyst can determine from the excerpt what produced the stain. Once again, the analyst should explain that this cannot be done out of context. Obviously more information is necessary such as: What was the original surface? Was it vertical or horizontal? What were the associated stains surrounding those presented? What injuries caused the bleeding? What other physical evidence was present which might support or refute any opinions made? An analyst does not make opinions based on tunnel vision, but rather by utilizing a holistic approach. Hopefully, the judge will preclude an attorney from conducting such "expert testing" procedures. They serve little, if any, function. In the same way, if the analyst is forced to answer a question about a specific book or article, he or she should always demand to see the citation before answering.

An attorney usually will not use leading questions during direct examination. Conversely, on cross-examination the attorney wants to control the witness and is likely to use leading questions. There are generally three types of leading questions: mildly leading, fairly leading, and brutally leading. Mildly leading questions often begin with words such as "is", "are", "was", "were", "do", and "did", while fairly leading questions start with words such as "aren't", "weren't", "don't", and "didn't". Brutally leading questions either begin or end with phrases such as " Isn't it true …?", "Isn't it a fact …?", "Won't you admit …?", or "Won't you concede …?"[5]

When these words come out of the attorney's mouth, listen to the questions carefully. If you are unclear about what was asked, you should not answer. State clearly that you did not understand the question and ask that it be repeated. If the question is a compound question, take each part separately, answering the first, then the next. If this is not possible, then try asking the attorney which question he would prefer to have answered first.

The analyst must recognize the attack for what it is and respond. The attorney is not looking for an answer; he or she is trying to confuse the witness, the jury, or both. A good counter to this technique is to pause after every question. Since the analyst is charged with answering the attorney's questions, he also has some control over the pace. Should the attorney interrupt the analyst while he is talking, the analyst can simply stop and wait. Once the attorney stops talking, the analyst can then ask the court to allow him to complete the answer if needed. Slow the pace down if possible and do not become flustered by the attorney's actions.

In answering any question be cautious of offering simple "yes" or "no" responses to complex questions because the attorney will often go to great lengths to keep you from explaining further. Never start an answer with "Yes, but," or "No, but." By doing so, you have already answered; the only chance to provide the full details considered necessary is to explain the answer first.

Using Demonstrative Aids in Court

Analysts should consider the use of demonstrative aids to assist in explaining their bloodstain pattern testimony to the court. Some of the common aids used include diagrams, charts, and photographs. Additional demonstrative aids include:

- 3-D computer graphic stills
- 3-D computer generated animation
- PowerPoint presentations

Recalling our discussion of Event Analysis in Chapter 14, 3-D rendered computer graphic stills can be created for each bloodstain event/event segment. These assist the jury in understanding testimony. There are several advantages to their use:

- They represent about one-third the cost of creating a computer animation.
- If the court rejects one or more of the pictures, they are easily removed. A moving animation is much more time consuming to edit. Editing, if allowed, must be accomplished in the time frame directed by the court, and with animation that is not always possible.
- The 3-D renderings direct the jury's attention away from the blood and gore of viewing photographs of the actual victims; thus, they tend to better hear the testimony.

3-D computer generated animations are effective, but very expensive to produce. The videos allow the court and jury to "see" the analyst's theory of what happened in some specific circumstance. Care should always be taken to explain to the jury that the computer did not "figure out" what happened, but rather it is simply showing what the expert's conclusions are regarding what occurred.

PowerPoint or similar presentation software packages are an excellent medium in which to present photographs, sketches, and other computer-generated images. One caveat, however, is to never make changes after sending a presentation to the court. The process of changing material is so easy that it is hard to resist making last minute improvements. However, the presentation before the court must be shown exactly as submitted to the attorney.

If not, some challenge will ensue. These software packages are very effective because it is easy to redact information in a matter of moments in order to please the court.

The use of hardware devices such as an Elmo helps the analyst in presenting detail from photographs or items of evidence. The item to be viewed is placed on the Elmo stand and the system projects its image to a screen or television. These devices allow for zooming in and out on the item, with very effective magnification.

Building Demonstrative Presentations Using Computer Resources

The ability of a jury to "see" the analyst's conclusion develop is very important in their subsequent acceptance of that conclusion. If the analyst simply takes the stand and talks for several hours, he or she might win over the jury, but more likely than not he or she will put the jury to sleep. The use of demonstrative presentations aid the jury in understanding the interrelationships of the evidence and how that evidence led the examiner to a conclusion. They also help keep the jury focused on the relevant information.

When instructing, the authors are routinely asked how we prepare some of the demonstrative presentations we share with students. The process is quite simple. We combine output from various software packages, creating clear, focused, and easy to manipulate demonstrative aids. The process requires a computer, three basic software packages, and a scanner. The particular brand of software purchased is of little importance, but we will describe the process using the brands we prefer.

The first package necessary is a presentation package similar to Microsoft PowerPoint. This program is the heart of the presentation and it helps to be familiar with the basic workings of the presentation software. All of the other programs will provide input to this package.

The second software package required is a CAD or a home design software program. These programs are commercially available from a variety of software publishers for under $100. Examples include Punch Pro and 3D Home Architect. They create architectural-style floor plans and 3-D views of the floor plan. Before purchasing the package, check to ensure that it provides the following features:

- A large furniture library
- Editing of the size of the furniture in the software library
- Rotation by degree of furniture items
- Export of 3-D rendered screens in a standard graphic file format (e.g., BMP or JPG)

The third package required is a human figure design package, such as Poser. These programs allow the user to pose virtual models in any position desired. The program should:

- Be easy to learn. You will not work this program all the time, nor will you use it fully. Nevertheless, when you need it you want to be able to use basic processes easily.
- Offer the ability to use different model formats (e.g., life-like, stick-figure, mannequin).
- Have the ability to import graphic file formats such as JPG or BMP as backgrounds for the program.

Finally, a scanner is required. This item is necessary for converting scene photographs and sketches into graphic files that can be imported into the presentation software.

A computer, the presentation software packages, and scanner are usually found in any police agency. They represent the bulk of the cost associated with purchasing these items. Home design software is relatively inexpensive and available from $100 and up. Human animation programs cost as much as several hundred dollars.

Before discussing the process of how to create a presentation, there are practical points to identify about designing the presentation. If ignored, they simply detract from or reduce the effectiveness of the presentation. These points include:

- Keep it simple. Fewer presentation slides are better.
- Screens should be orderly and uncluttered, and the lettering should be large. Do not try to jam too much information into a single screen.
- Choose a conservative color scheme and a clear readable font.
- Whenever possible, eliminate photos that contain gore and bodies. These detract from the presentation and distract the jury.
- Keep conclusions out of the presentation itself. The purpose of the presentation is to demonstrate the evidence and interrelationships. The analyst will testify to the specific conclusion. Failing at this point, the judge may order redaction of certain information.

The typical presentation method in bloodstain pattern analysis is to walk the jury through the scene, highlighting important stains. To do this effectively, the analyst creates a 3-D representation of the scene.

Using the CAD or home design software, the analyst first creates a 2-D sketch of the scene or room in question. The information required by the program from the crime scene sketch and crime scene notes includes ceiling heights, furniture sizes, and general room and opening dimensions. Once the general room layout is complete, the analyst inserts furniture and fixtures from the software library and places them appropriately. It is important to recognize that this model is a representation of the scene, *it is not to exact scale,* nor is it intended to be. The model will not match the scene in every detail, but wherever possible, ensure that it does. Furniture appearance is a major problem. Seek items that are similar to the actual scene furniture, and then size them accordingly.

Once the floor plan and furniture are complete, the analyst can render 3-D views from various perspectives. The analyst does this by aiming a virtual camera at specific points in the 2-D plan. The software then renders a 3-D view of what the viewer would see standing at that location and looking in the given direction. The view or views required by the analyst depend upon the location of items of evidence. The same rules apply to the virtual camera as they do with a normal camera. Whenever possible, keep the lens and primary subject aligned; do not interject odd or inappropriate angles. Do so only if necessary, as in the case of an item nearly hidden or in an abnormal position. After initial camera placement, almost all programs allow the user to move the virtual camera "on the fly." This allows the user to tweak the camera position and see the immediate result. This will ensure getting the best view for the presentation's purpose.

A good starting view for any presentation is an overhead view. Like a crime scene sketch, this view will help orient the jury to the model (see Figure 15.1). Create other views from "within" the room as needed, and then export them (see Figure 15.2). Most export methods produce a BMP graphic file, which can then be imported into the presentation software. Note that most home architect software has two export functions. The first is found in the main screen File menu. This function exports the entire plan and creates a

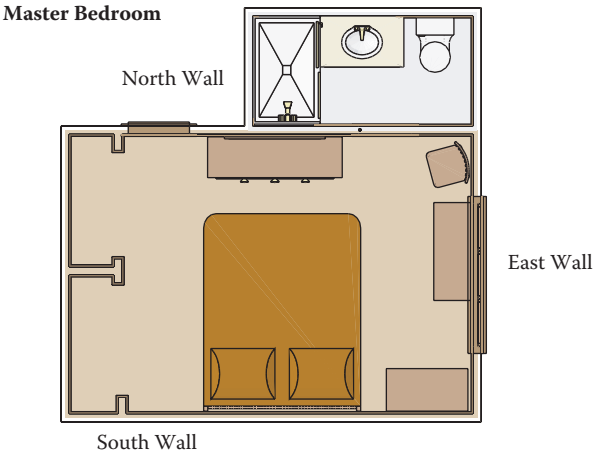

Figure 15.1 An overhead view helps orient the jury to the scene and items of furniture. Used in conjunction with the crime scene sketch, the jury has a full understanding of where things are.

Figure 15.2 These programs allow the placement of a camera to create a view from anywhere in the scene. In this example, we show the view across the room from the doorway. Whatever view is necessary, the software will usually accommodate it. The view is then exported as an image (usually a bitmap) and imported into the presentation software.

DFX or similar file. This is not the export needed for the presentation. Exporting a 3-D room view creates a graphic image file. This function is found in the File menu only when the 3-D rendered view is on screen.

Be sure to save the exported files in a temporary folder where you can easily retrieve them. If you let the software put them in some default directory on the computer, you will find it more difficult to locate them when you need them.

The room views are raw material for the presentation. Before they can be manipulated, they must be imported to the presentation software. The following instructions apply to PowerPoint, but whatever software is used the process is not much different.

First, open a new presentation file using the blank slide format. If you created three different room views, you will then need to start with one presentation file with three blank slides.

In the standard slide edit mode (where you see one slide at a time), choose "Insert" then "Picture" then "From File." This will bring up a dialog box. Using the "Look In" option, browse to the directory where you saved the room view files. If you see no files listed, check the "File Type" option to ensure you have the right file type chosen (e.g., picture files, Windows Metafiles). The system allows you to preview what the picture looks like, so you can be sure you have chosen the file you want. Choose the file needed and select "Insert." At that point, the software will return you to the edit screen and the image of the room view will be displayed on the slide. Size the image as necessary. This view is an image, static and unchangeable except for size in the presentation software. If this image must be adjusted, return to the home design software, make the change, then save and import it back into the presentation software.

Repeat the insert process for each room view you created, but be sure to move to a blank slide in the presentation before importing each new room view. Once created, keep the basic slide intact because you will likely need to make several slides using the same room view. Duplicate it, as needed, before annotating or adding to it. This will save a significant amount of time. To duplicate a slide, highlight the desired slide and choose "Insert" then "Duplicate Slide."

After duplication, the analyst can annotate and add graphics to the slide as required. Annotations, arrows, and circles are used to explain and direct the viewer's attention to specific locations where evidence was found. Be sure to use contrasting colors and a readable font.

Photographs are another integral part of the demonstrative presentation. They may include crime scene photographs or photographs of standards created in some experiment. To include a photograph in the presentation, start by scanning the images you need. Be sure to use the "Auto Balance" or "Enhance" feature in the scanner software. This will usually lighten the image, making it easier to view. If for any reason this enhancement causes an unwanted effect, before saving the file simply choose "Edit" and "Undo" in the scanner software. Name the image files created so they are easily recognized. Save them to the same temporary directory in which you saved the room views. In combination with 3-D views, these photographs will allow the jury to better understand where specific stains were found (see Figure 15.3 and Figure 15.4).

Do not be afraid to crop scene photographs before importing them into the presentation. As long as you can establish from which photo the cropped image originated, the court will not object. Cropping allows the analyst to eliminate offending gore or bodies, or to focus on some specific area in the photograph.

Once the scene images are scanned, return to the presentation software program and follow the procedures used to import the room views. In the standard slide edit mode (where you see one slide at a time), choose "Insert," then "Picture," then "From File." This will bring up the dialog box. Once again using the "Look In" option, browse to the directory. There the preview window will assist in locating the scene photo you want. Once you locate the image, select it, and then choose "Insert" from the dialog box. The screen will return to the slide edit mode, where you can size the picture as needed (see Figure 15.5 and Figure 15.6).

Human figure animation software is used to create figures in various poses. These are imported into the presentation software in a similar fashion. A significant difficulty exists in combining both a 3-D room view and a figure. Based on the export method of each

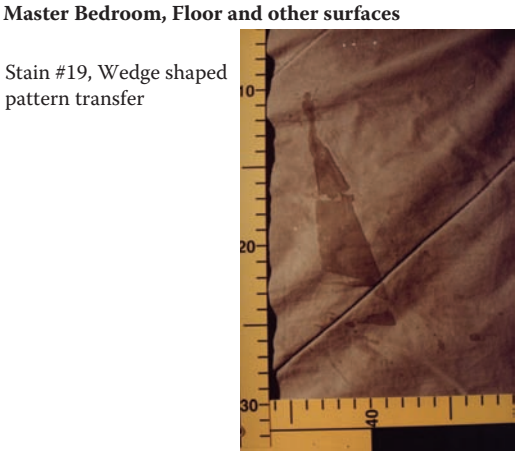

Figure 15.3 Part of a series of presentation slides shown in a murder trial. This slide incorporates an evidence photo of a specific stain; the slide provides specific information regarding its identity (Stain 19) and general location (Master Bedroom).

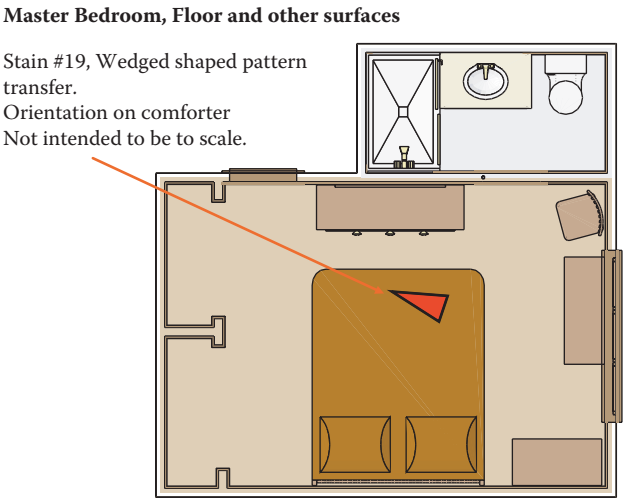

Figure 15.4 This slide combines the image of the overhead view created in the CAD software with arrows and graphics to show the specific location of Stain 19 (Figure 15.3) in the scene.

image, intermixing the two is nearly impossible. There is one alternative. Programs like Poser allow the analyst to import a scene photograph into the figure software and scale it to match the figure. The scene photograph becomes a background for the Poser figure. Once this is done you can export the combined image in the same way you would any other Poser image. The human figures can be combined in a variety of ways with other pictures to illustrate various points (see Figure 15.7 and Figure 15.8).

Through these software packages the analyst can create any number of presentation slides to help explain the location and interrelationship of various items of evidence or the results of some experiment conducted. The authors prefer a presentation that alternates between a scene photograph and a room view. This combination will ensure that the jury can see the particular stain being discussed, and that they know exactly where it is in the room.

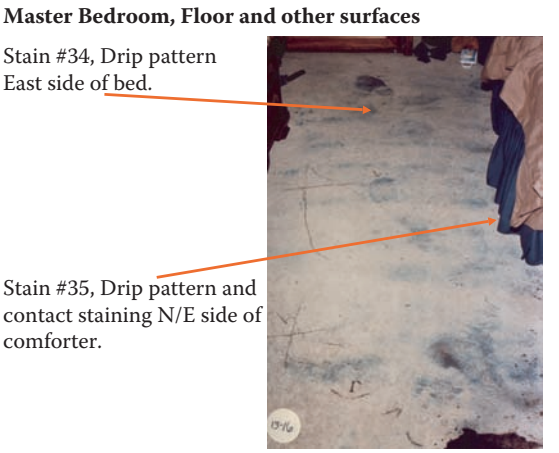

Figure 15.5 This slide shows two stains on the floor of the bedroom (Stains 34 and 35) using a crime scene photograph. The annotated arrows allow the analyst to show exactly where on the photograph the jury should look to find the item. This is effective when multiple stains overlay each other in a given photograph.

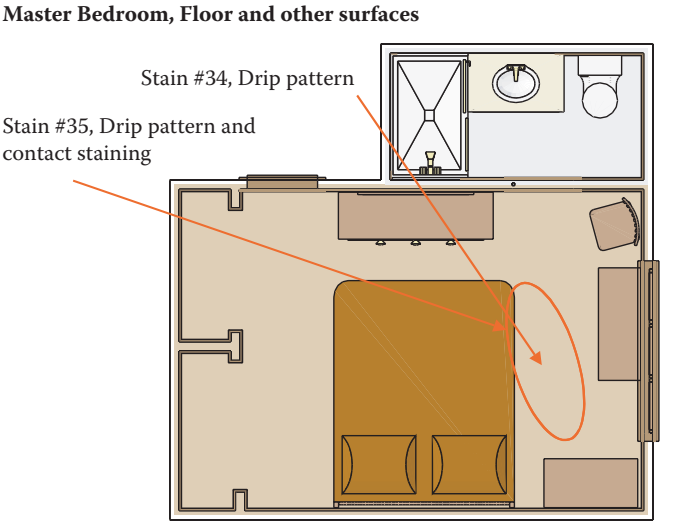

Figure 15.6 Another overhead view orients the position and extent of the two stains from Figure 15.5, helping the jury to better understand what the analyst saw at the scene or in the evidence.

Bloodstain Pattern Analysis Software Applications

A number of automation programs may aid the analyst both in analysis and in creating demonstrative aids. TRACKS® is one such program. Designed by Dr. Alfred Carter of Forensic Computing of Ottawa, TRACKS® allows the user to adjust variables regarding blood droplets (i.e., speed, angle, size) and discover what these changes do to the droplet's flight path. The reader may recall seeing several figures produced from TRACKS® models in Chapter 8. Although primarily intended for students, screen shots taken from TRACKS® could be utilized in the courtroom to clarify teaching points to the jury.

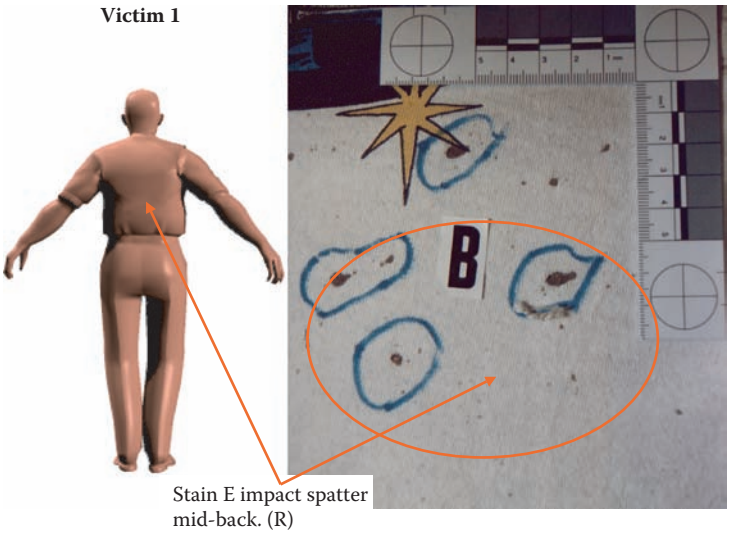

Figure 15.7 In this slide, human animation software was used to create the "representation of the victim." Just as we used the scene views and photographs, this slide allows us to specifically orient the position of Stain E to its position on the body of the victim.

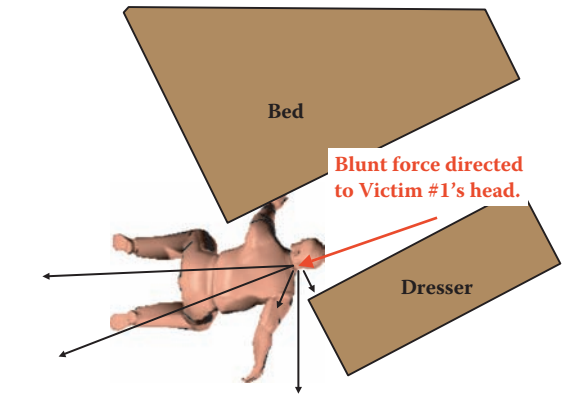

Figure 15.8 After placing the "model" in a position, we can generate additional graphics to demonstrate the position and relationship of the figure to other objects in the scene.

Currently there are few other "tutorial" applications available in the field of bloodstain pattern analysis. The creation of an expert system offers one possible area for development. The expert system is an early form of an artificial intelligence (AI) programming technique. It consists of a database of knowledge held by a given expert or group of experts. This database is combined with a rule base, which is the logic process the expert applies to solve issues or questions. Together the information and methodology walk the student through a given problem, typically by the system asking specific questions and the student giving answers. Currently efforts are underway in France to create an expert system for classification/taxonomy, using similar decision trees as those described in Chapter 3. Such developments will clearly aid the analyst, but will have minimal function in the courtroom.

Backtrack/Win and Backtrack/Images are software packages that allow the user to evaluate spatter patterns. The software, using standard equations, does the tedious math necessary to define the area of origin. The software then presents the data in both text and graphics. It uses standard equations and physical laws to determine where a droplet may have originated. The programs provide an accurate estimate or representation of the spatter event. Both programs were explained and demonstrated in Chapter 8. Although it would be inappropriate to run the programs in the court, screen captures can be inserted effectively into demonstrative presentations.

Another developing trend in computer-aided analysis is the use of imaging software. Too often analysts are presented with poor quality photographs of evidence and stain patterns. Imaging software allows the analyst to clean up these photographs and view them in a more functional manner.

Color modification and manipulation are very similar and well suited to bloodstain pattern analysis. In this instance, a particular color in the image is chosen and modified so it stands out more clearly. Color manipulation works well because the computer distinguishes between colors or shades of colors more effectively than the human eye. The analyst simply points to the area in question and the computer modifies the given pixel color at that location to whatever color the analyst desires. This kind of modification allows better human discrimination by increasing the contrast or color shade of all similar pixel colors in the picture. Of particular note, this method often enhances transfer patterns, allowing better visualization.

A simple form of this process is color reversal. Consider Figure 15.9 and Figure 15.10, which demonstrate this technique in enhancing a spatter and transfer pattern. In the original photograph (Figure 15.9), the dried bloodstains appear dark and do not stand out well against the blue color of the pants. Reversed (Figure 15.10), the pants become red while the patterns become white, making their form and boundaries much more evident.

A major concern in image enhancement and manipulation is the difference between alteration and enhancement. Reeves, in a presentation to the IABPA, made the point that enhancement increases the value, while alteration implies a change to the original image. The difference between the two is not that great.[6] The analyst walks a very fine line in the business of image enhancement — one in which the court may or may not approve of the methods. To counter these concerns, the analyst should document each manipulation routine employed and its overall effect, and wherever possible create an exhibit reflecting each stage of the enhancement. As digital cameras and their capabilities become better understood by the court, attacks against digital enhancement are likely to disappear.

Another area new to scene reconstruction combines both image enhancement and a process that might best be called a simulation. E-Systems of Dallas developed an image enhancement process clearly suited to both bloodstain pattern analysis and crime scene reconstruction. The method employs techniques and algorithms originally developed for space reconnaissance imaging. E-Systems refers to this process as perspective transformation.

In a case involving one of the authors (Bevel), E-Systems enhanced a photograph of a tile floor with a large bloodstained area (see Figure 15.11). Within the bloodstain is a voided section of specific interest. The area shows indications of the presence of a footwear pattern. The problem associated with the photograph is the oblique angle at which it was taken. This angle introduces obvious distortion to the voided section and presents the

Figure 15.9 An unenhanced computer-generated image from a photograph of a pair of bloodstained pants. Although spatter and stains are evident, the dark colored blood on the blue background makes viewing difficult. (Photograph courtesy of Norman Reeves.)

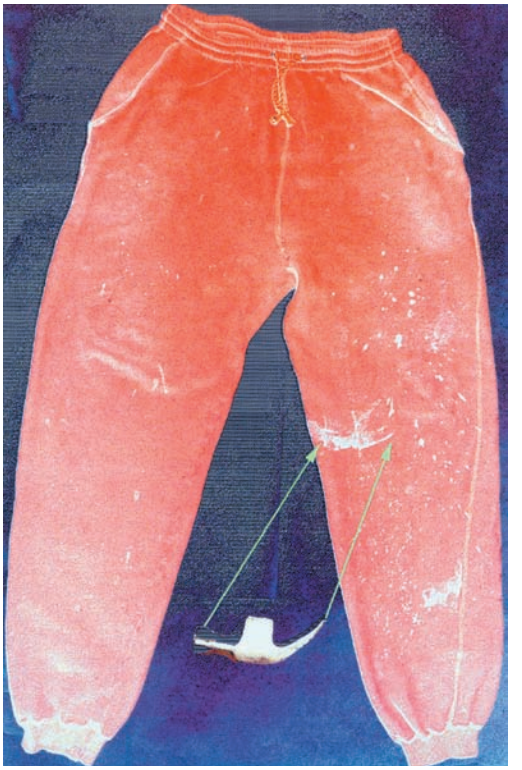

Figure 15.10 An enhanced image of the same photograph in which the analyst inverted the colors. The blue background becomes red and the dark bloodstains become white. The increased contrast allows for a more functional evaluation. The analyst then superimposed a weapon into the photograph for comparison to a pattern transfer. (Photograph courtesy of Norman Reeves.)

viewer with a glancing view. Unfortunately, this was the only photograph available of this critical evidence.

Using advanced photogrammetric techniques, E-Systems was able to correct this view. The corrected view, based on the data present in the original photograph, allowed the viewer to actually look down onto the floor.[7] Although no scale of reference was included in the original photograph, the computer model used the dimensions evident in the tiles of the floor to build a control grid (see Figure 15.12). This allowed a projection of the original oblique perspective to the vertical perspective. The pattern transfer itself was then enhanced in the image, using a mathematical model that corrected imprint detail missing from the original image. Figure 15.13 is the enhanced version of the photograph.

These methods go far beyond the simple image enhancements available using off-the-shelf computer software programs. To some extent, E-Systems' methods actually allow the analyst to correct photographic mistakes made during the initial scene processing. These methods are obviously not appropriate for every single case, but in instances where a significant enhancement might make the difference, they are available.

Figure 15.11 In this crime scene photograph there is evidence of a footwear impression in the stained area. Unfortunately, the oblique angle of the photograph causes a major perspective distortion, making the photograph of no use to the analyst. Also, note the lack of a scale of reference. (Photograph courtesy of Henry Muse, Dallas, TX.)

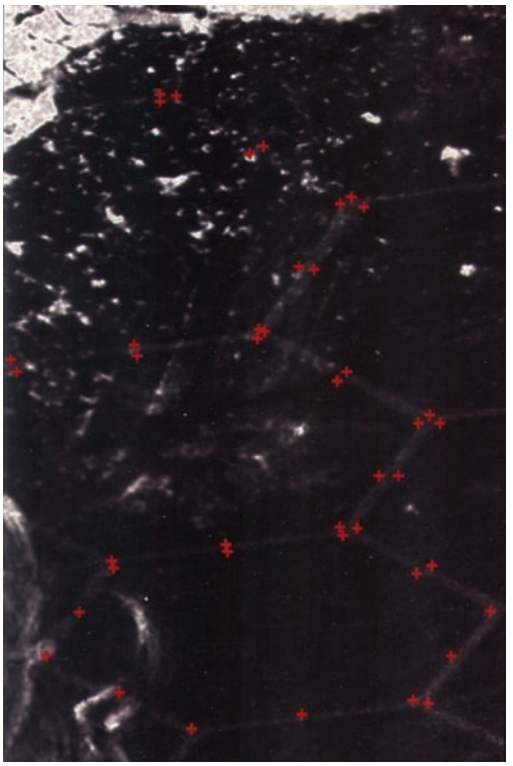

Figure 15.12 Using the tiles as a scale of reference, the computer program was able to create a control grid, which allowed the transfer of the perspective from the original photograph to the vertical perspective. (Photograph courtesy of Henry Muse, Dallas, TX.)

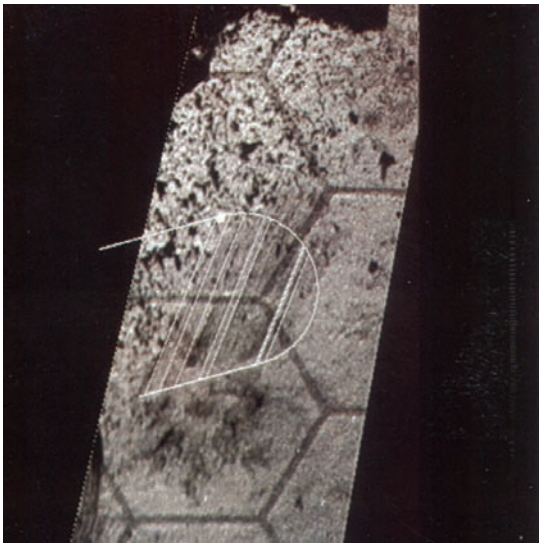

Figure 15.13 E-Systems of Dallas was able to enhance the original photograph (Figure 15.11) to this end product. Using a mathematical model, they filled in the missing detail from the pattern transfer and highlighted the entire enhanced pattern in white. Although certainly an "alteration" of the original image, this is an example of a substantive type of programming technique that may well serve analysis and reconstruction in the future. (Photograph courtesy of Henry Muse, Dallas, TX.)

Summary

If the reader remembers nothing else from this chapter, remember always that the analyst is a fish out of water in the courtroom. The rules, in effect, have little to do with the analyst's own. It is easy to be drawn in by skillful attorneys who will turn a simple slip of the tongue or minor mistake into a major production. In doing so, they know the evidence will lose center stage as the jury becomes enraptured by the theatrics.

By remaining within comfortable limits in the conclusion itself, by preparing properly, and by applying careful attention to the manner in which they testify, analysts can preclude many opportunities to be party to such courtroom theatrics. Once the evidence is heard, so long as the analyst remains an unbiased and objective expert, the court or jury must ultimately decide to accept or reject the testimony.

A critical concern for the analyst is preparing for Daubert style challenges. Not only must analysts be prepared to defend their own credentials, but they must come prepared to defend the discipline as well. This means understanding the foundation and history of the discipline, articulating a concise methodology based on scientific method, and showing that the analyst utilized such a methodology.

Finally, the analyst must recognize that explaining a conclusion often demands the use of demonstrative evidence. As bloodstain pattern analysis is a graphic discipline, it lends itself to demonstrative presentations far better than many other disciplines. The analyst should use the various automation applications available to build functional demonstrative aids that will help the jury understand the scene and the analysis.

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Experimentation in Bloodstain Pattern Analysis 16

In unraveling an investigative puzzle, the analyst will often conduct some manner of experimentation in order to try to clarify a given circumstance. This is particularly true for the bloodstain pattern analyst, who routinely is asked to decide if a particular set of circumstances can create a questioned stain.

The goal of any such experiment is to simply include or exclude some event or set of events as a source of the questioned pattern. With this in mind, we will consider some general guidelines and routinely encountered pitfalls that affect the reconstruction effort, as well as look at the basic principles for designing case-specific experiments. By considering the following factors and guidelines, the analyst is more likely to maintain investigative focus. These guidelines will also help prevent the reconstruction effort from becoming too subjective. There are five initial considerations:

1. *Define what is at issue.* What exactly is the analyst trying to establish or learn? Be clear from the start and maintain focus throughout the effort.
2. *Consider all viable explanations for the result or pattern.* The analyst cannot go looking for "his" answer. It is data that defines the conclusion and not the conclusion that defines the data. As such, it is best that the analyst at least consider all viable possibilities.
3. *Eliminate the ridiculous.* Particularly when considering bloodstains, given a little time and ingenuity the analyst can reproduce a particular pattern in any number of ways. For instance, a misting stain is easily created using a spray bottle, but was a blood-filled spray bottle found in the scene? Certainly consider all possibilities, but do not waste investigative resources and time on flights of fancy.
4. *Brainstorm with others.* The analyst cannot always rely on himself to maintain objectivity. Ask investigators, analysts, attorneys, or individuals not directly involved for input.
5. *Concentrate on elimination.* The analyst should concentrate his effort on eliminating possibilities that are "not consistent." Do not put emphasis on "identifying" the event. It is not the case that the analyst can associate a set of circumstances to a specific event and always absolutely exclude all other possibilities. Scientific method works on the idea of falsification. Simply by eliminating impossible circumstances, a level of clarity is brought to the situation.

Considerations for the Design and Conduct of Experiments in Bloodstain Pattern Analysis

As it is almost inevitable that the analyst will be presented with a situation demanding experimentation, each bloodstain pattern analyst needs a basic understanding of how to design and use experimentation in support of his analysis. This understanding begins in a basic bloodstain pattern analysis course, where practical exercises and experiments are designed to expose the student to the most common mechanisms of bloodstain

production and the nature of the resulting stains. These exercises offer the analyst exposure to experimentation, including the need to identify a specific objective or purpose and the necessity of controlling variables. What is learned here will act as a foundation for subsequent casework. These experiments, however, do not provide a comprehensive exposure to the vast array of bloodstain producing mechanisms, nor to the variations of circumstances that might be encountered in casework. Analysts will often find complex patterns produced through very dynamic interactions or that result from a combination of crime scene variables. When presented with these circumstances, case-specific experimentation is often necessary.

There are numerous texts available on the subject of scientific and research method, and a single chapter will not address every aspect of experimentation. This is, however, an important area within our discipline and needs to have, at minimum, a cursory discussion.

In bloodstain pattern analysis, experiments are usually accomplished in an effort to identify the best explanation among the multiple hypotheses developed that might explain the source of a questioned stain or pattern. This is accomplished by eliminating among the multiple hypotheses those that are impossible. These experiments follow the scientific method as described in Chapter 4. Scientific method involves identifying a discrete question, gathering data to resolve the problem, forming a hypothesis to explain the observations, making predictions for the hypothesis, testing each hypothesis, and then drawing conclusions to confirm or refute each hypothesis. Applying scientific method in the experiment usually demands engaging in multiple tests, as the analyst must control all variables and change only one variable in each test. Without this control, the analyst would not be able to state with any level of certainty how each variable altered the resulting pattern.

In effect, the analyst looks for cause-and-effect relationships between the variables considered in an attempt to explain how these variables might interact to produce the questioned pattern. The hypothesis is a best guess at what this cause-and-effect relationship is.

In the available literature and references, it is immediately evident that there is no absolute method or agreed upon series of steps that universally define how the scientific method should be carried out and applied. Irrespective of author, the scientific method has certain common themes. The following is a discussion of these common steps as they relate to conducting scientific experimentation.

Identify the Investigative Question

Before conducting a meaningful experiment, the analyst must first know what question he or she is trying to answer. Thus, the analyst must form and state a purpose for any experiment. This statement is also known in crime scene analysis as the investigative question (IQ). This investigative question is specific and narrow in focus. The broader the question, the more likely there will be an increase in variables. The more variables involved, the more difficult it is to design an experiment that can functionally test those variables independently. When presented with a broad issue, the analyst will find it necessary to break the broader question up into more discrete issues. Each of these smaller issues or questions is asked and answered independently, and the results are then combined in an effort to

answer the broader question. In bloodstain pattern analysis, the most often posed investigative question is: "Was a particular mechanism the source event for this pattern?"

Initial Observation and Information Gathering

The need for experimentation begins with the initial observations of the scene and the analyst's consideration of the various reasonable events that could have produced the bloodstains in question. Given the class characteristic nature of bloodstain pattern analysis, it is not uncommon that there may be several possible source events associated with any given scene. The analyst uses his or her experience and/or past experiments as an initial evaluation method. If this initial evaluation does not answer the question in the analyst's eyes, then specific experimentation may be necessary.

After gathering all available investigative reports, lab reports, autopsy protocols, photographs, diagrams, and physical evidence, the analyst studies these to become familiar with all associated details. When preparing for the experiment, it is a good idea for the analyst to review recent literature, textbooks, or other professional publications, looking for any information or ideas that might impact on the experimental design.

Identify Variables and Form a Hypothesis

Using the information gathered, the analyst makes an educated guess, based upon his training, experience, and past experiments, as to what types of actions or variables may have created the stains or patterns in question. When considering these possibilities, if a possibility is excluded within the scene or event in question, it does not need to be tested. Mike Haig refers to this concept as the "limited universe."[1] Limited universe simply means there is no need to include every possibility within the universe that might explain the pattern. Instead, we consider only those actions that appear reasonable within our limited universe of the crime scene in question.

This step of identifying the variables possible is critical before the analyst can consider moving forward in the experimental phase. Each possibility considered viable becomes a hypothesis that should be tested.

Of equal importance to the analyst is the consideration of what variables affect each individual hypothesis. Examples might include the volume of blood involved, the nature of the impacting force, or the orientation of the weapon to the wound site. The analyst must consider how that variable will be altered during the experiment. While testing these variables, the analyst must control and change the variables one at a time. If more than one variable is changed at each stage of testing, it may be difficult to know or recognize which altered variable is actually changing the pattern observed in the experiment. Keep in mind, however, that oftentimes these variables are linked and work together to cause the end result. In the beginning efforts, it is often best to work with those variables the analyst believes are acting independently of each other.

As indicated, the initial hypotheses are based on prior training, knowledge, experience, case facts, and other experiments conducted in the past. Generally, the analyst answers the question of what caused the observed bloodstain pattern by comparing it to previous experiences involving similar patterns. This experience provides the analyst with

a belief of what basic actions can be excluded as a source (recall our discussion of the six basic types of patterns from Chapter 1), and what actions might explain the pattern. If the issue surrounding a given hypothesis is not unique, the analyst's prior experience may be adequate to answer that aspect without creating a specific experiment (e.g., the basic nature of a radiating impact spatter pattern). In more complex instances, however, the hypothesis may involve unique or never before encountered issues demanding significant experimental effort and design.

Design a Functional Experiment to Test Your Hypothesis

In order for an experiment to provide valid results, it must be designed correctly. In part this means considering the variables that must be tested during the experiment, determining how they will be altered, and deciding which variables may require linking. Design generally requires creating a control test. This control is an additional experimental trial, done under the same conditions as the other experiments, except that no variables are changed during the course of the control experiment. The control acts as a neutral "reference point" for comparison. It ensures that some unrecognized environmental factor is not in play in the analyst's experimental procedure and allows the analyst a greater level of confidence that any change observed in the actual experiment is an effect of the variable that was altered.

Experiments are typically done a number of times, simply to guarantee that the effect observed is reproducible. Reproducibility is a crucial requirement. As the reproducibility of the observed effect increases, the chance that the analyst has introduced some experimental error or is observing some random effect is reduced.

Obtain Materials and Equipment

After considering the design of the experiment, the analyst should make a list of the equipment or items needed. These are gathered and prepared in advance. Remember, it is important to change only one variable during each iteration of the experiment. Time is a variable, so if the analyst is unprepared and stops the experiment to obtain or prepare some aspect of the experiment, he is in effect introducing a new variable.

A significant consideration for materials is the need for human or animal blood and whether that blood will be freshly drawn or from a blood bank. In spatter creation experiments, there is little or no difference in the results based on the type of blood used, but in drying, clotting, or serum separation experiments freshly drawn blood is usually necessary.

Conduct the Experiment and Record the Data

Experiments are accomplished changing one variable at a time. Thus, a series of experimental runs will make up any experiment. During each run, the analyst should record how and in what way, if any, the changed variable affected the stains under study. Documentation of the experiment should be in the form of written notes. These notes will include the nature of the variable changed, specifically how it was changed, and the observed change in the pattern that resulted from the manipulation of the variable. The nature of the observations may be descriptions of what was noticed or observed, or it may be actual measurements of changing aspects of the stain pattern (e.g., size, volume, or drying time). In addition to

maintaining accurate notes, the resulting observations can be captured using photographs as well. Ultimately, all of the observations will be critical when drawing conclusions at the end of the experimental procedure, so clear and precise documentation is needed.

Analyze and Summarize Results

After concluding the experiment, the analyst must consider the interrelationship of the observed effects in the experimental stains and the variables altered throughout the experiment. These effects are then considered in relation to the questioned stain from the scene in an effort to resolve the investigative question. After review, it may become necessary to redesign the experiment itself, in order to more accurately test an observed effect and resolve minor issues or contradictions between the results and the questioned stain. It should be noted, however, that bloodstain pattern analysis is class characteristic evidence; thus, it is doubtful that any experimental procedure will reproduce every single aspect of a questioned pattern. There are simply too many variations in the variables from the scene, many of which are and will remain unknown to the analyst. Do not expect the experiment to produce an exact "copy" of the questioned pattern.

Once all experimentation is complete and correlation of the variable's effect on the pattern is defined, the analyst should summarize these findings. This can be in a written statement or by the use of tables or graphs. Based on the observed results, the analyst then seeks some conclusion that may assist in confirming or refuting the hypothesis in question.

State the Best Explanation

In terms of defining source events, ultimately the analyst is left to consider the viable possibilities and the observed effect created by changing variables, and to decide if the observed experimental results support or refute any of the possibilities. Obviously, it would be best if only one hypothesis is supported, but this is not always the case. A hypothesis cannot be ruled out if, through experimentation, the associated mechanism produces similar type stains. However, this does not prevent the analyst from offering an opinion of the "best explanation." Wilson commented on this issue, stating, "If two different hypotheses fit the observed facts and if one is clearly simpler than the other, it is customary to accept the simpler until further evidence causes its rejection."[2] This is a simple application of the principle known as "Occam's Razor," which states that the best theory is the one with the fewest independent assumptions.

Whatever the circumstance encountered, the analyst attempts to use the observed trends and results from the experiment to answer the original question. The end result of this analysis is generally achieved by identifying the "best explanation" based on the variables that were tested.

In considering this concept of best explanation, few objective analysts would claim that any hypothesis, however extensively tested, was a statement of absolute, universal truth. A hypothesis can always be proven false, but rarely can one be proven or confirmed as the absolute answer to the issue with complete certainty. Thus, the conclusion expressed is simply a best explanation given the data. Remember that it is impossible to test all given conditions and possible variables; there are simply too many unknowns in the scene. Thus, someone with a slightly different perspective may find a condition under which the analyst's best explanation hypothesis does not hold true.

Maintaining a Reality Check, Comparing against the Crime Scene

A common error that analysts make in experimentation is not comparing their opinions against the known events within the crime scene, autopsy, and lab reports, or in not applying known variables from the scene to the experiment. If, for example, a pattern is ultimately identified as an arterial spurt, then the autopsy should identify that some artery was in fact compromised. If it does not, it is imperative that the analyst speak with the ME and see why this contradiction exists (e.g., generally MEs only report damage to major arteries, which does not eliminate the existence of smaller damaged arteries). Another example of checking reality is found in expectorate action. The analyst should validate that the victim had blood in his air passage or that the autopsy identified aspirated blood in the respiratory system.

It is just as important to apply Haig's "limited universe" concept to the conclusions offered. Were the mechanisms and variables evident in the crime scene faithfully reproduced as closely as possible? If not, the results of such experimentation are unlikely to assist the analyst in refuting or corroborating a given hypothesis. There have been cases in which analysts (consciously or subconsciously) "tweaked" the experiment in order to reproduce a questioned pattern. In doing so, they leave the reality of the crime scene conditions behind and introduce variables that were not in play at the scene. If there is no evidence or information available to suggest that some action occurred in the scene, then it is a mistake, if not dishonest, to identify or insinuate that such an event is the possible source for the questioned pattern.

Experimental Errors

Wilson commented on the basic nature of science, stating, "All science rests on the idea that similar events occur in similar circumstances."[3] One of the greatest difficulties in bloodstain pattern analysis is the inability to recreate exactly the events from the scene. No one can create identical circumstances found in beatings, shootings, and other bloodstain producing events. These situations are simply too dynamic. No two circumstances are identical; at the very least, they are different in time and place, as well as many other aspects. These difficulties may lead to errors in experimentation.

If after experimentation all observed results are inconsistent for the various hypotheses, this may suggest some form of experimental error has been introduced into the design. The obvious questions become: Have all viable alternatives been examined and were the possibilities too refined (e.g., a single position for the application of the weapon)? Designing experiments requires a critical eye to evaluate the experimental design, both in the initial design stages, and later in an effort to determine if experimental errors are in play in the observed results. When encountered and recognized, such errors demand rethinking the design of the experiment. Two procedures will assist the analyst in identifying and correcting such an error. First, the analyst should review each step of the procedure to find the source of potential errors. Second, it is often helpful to have a second analyst review the procedure and experimental design. Sometimes the analyst will miss an obvious error in the experimental design, while a "neutral" analyst using a fresh perspective will easily identify the problem.

If the analysts apply themselves to their design effort, then the most common error encountered is simply a random error introduced into the experiment by doing something

differently from one experimental run to the next. An example of this would be when the analyst fails to clean some part of the equipment used and, in doing so, alters (i.e., increases) the amount of blood introduced in each iteration of the experimental run. The analyst must faithfully follow the experimental design in order to eliminate these random errors.

Pitfalls to Experimentation and Reconstruction Attempts

There are always pitfalls in any effort directed at a bloodstain or reconstruction attempt, and these issues carry over to the experimentation conducted in support of the reconstruction. The following are some of the more common pitfalls to consider.

- Group think. The group involved may form a type of tunnel vision and collectively eliminate concerns that individual members clearly recognize as important. In recreations we often employ a group effort and "group think" concerns are common. Any concerns or criticism by team members of the methods employed should be objectively considered.
- Designing an experiment to prove your result. Since analysts control the variables, it is entirely possible that they may either consciously or subconsciously create a circumstance that defines exactly what they want. For instance, if trying to disprove that a beating caused a stain, the analyst could fail to use enough blood to create spatter. Thus, the weapon involved would obviously not cause spatter.
- Failing to take a holistic viewpoint. Tunnel vision in the individual or the group can eliminate objectivity and doom experiments to failure. As described, design the experiment around the case facts. Consider the results with those same facts in mind. If analysts know they are dealing with a contact wound, then recreating a non-contact wound fails to consider the case facts. The analyst must consider all known facts and information, then ensure the experimentation accounts for and includes that knowledge.
- Confirmation bias. The simplest way to explain confirmation bias is that the individual starts with a conclusion and then seeks data that supports it. Rather than trying to disprove a possibility, which is the most effective function of scientific method, the analyst simply seeks data to support his specific theory.

As a final consideration, be cautious in the exclusion of events. If the analyst chooses to exclude some event as being possible, then he must have a foundation for exclusion. "Gut feelings" and "Because I think so" are not adequate reasons for absolute exclusion in a reconstruction. When all is said and done, the analyst's conclusion must be in agreement with his experimental results.

Case Example 1— "Painted Fibers"

This example involved an accused who had bloodstains and tissue on the front of his shirt allegedly from a shooting event involving multiple parties. The critical question was how these stains got on the shirt. Were they contact or back spatter? As this issue was crucial in deciding if the accused was involved, it received significant attention. One hypothesis presented in the case was that the stains were contact transfers from brushing up against

the victim. The blood in the questioned pattern was checked and did belong to the victim. Additional observations reported to support this hypothesis were that individual fibers or threads coated with blood were present. This observed effect was referred to as "painted fibers" that were found disassociated from the spatter. Interestingly enough, the concept of these "painted fibers" had never been introduced, discussed, or studied in any reference, nor had any study been offered in any professional journal or meeting prior to the trial. The concept was presented to the jury without any peer review. Nevertheless, it was stated that these painted fibers or threads would not occur as a result of the back spatter associated with a shooting event. Thus, as told to the jury, the presence of the painted fibers or threads on the shirt in question proved the stains had to be a function of contact transfer and conclusively eliminated back spatter as a source event. Lacking any prior discussion or research on this issue, and because no prior experiments involving back spatter from shooting a firearm into a wet blood source had produced such a result, the painted fibers seemed to support the hypothesis of a contact transfer.

Presented with the situation, the opposing analyst was left to address if any other variables were present that might affect or produce the resulting painted fibers. One obvious variable in this case was the probability that the shirt involved was damp. The suspect had been present at a ball game prior to the event and was clearly sweating from his participation. This factor introduced another variable that required testing, since all of the prior experiments involving back spatter (done by this author and others) had always used dry clothing. In these instances, the only observed result similar to the painted fibers was the creation of tiny spheres of blood on the threads. No known effort had been directed at experiments involving damp or moist fibers or threads. In order to evaluate this new hypothesis, an experiment was designed in which the fibers or threads were lightly dampened and then impacted by gunshot back spatter. The result of this experiment was the small spheres still landed on the fibers, but with the addition of the damp clothing these tiny blood spheres wicked or migrated along the fiber or thread and produced the "painted" appearance observed in the actual case (see Figure 16.1).

This new knowledge of the effect of damp fibers presented another consideration and wrinkle to the case. In and of itself it did not resolve the original question of what caused

Figure 16.1 A "painted fiber." After appropriate experimentation (e.g., considering and testing all viable possibilities), it was established that "painted fibers" could be produced by both contact and gunshot. In the context of the case, they served no function in answering which of the two mechanisms was more likely.

the painted fibers. The fact that painted fibers or threads occur from back spatter landing on damp clothing did not disprove the transfer hypothesis presented at trial. It simply showed that the existence of "painted fibers" could not be used as a foundation to claim that contact transfer was the only viable source of the pattern in question. As it occurs in both instances, the painted fiber becomes a moot point in identifying the questioned pattern as either contact or back spatter.

Case Experiment 2 — An Odd Impact Spatter

In this example, a female was found in bed on her back. A .38 revolver was on the bed beside her. There was a hard contact entry wound to the right temple, with a right to left and down to up trajectory. There was no apparent exit wound (see Figure 16.2).

The primary investigative question was how the bloodstains on the wall (Figure 16.3 and Figure 16.4) could have been created from this shooting occurrence. The stains were approximately 6 ft away from the victim's head as she lay in her final position on the bed. The stain indicated a distinct volume of blood was involved, with directionality upward and slightly to the left. There were a large number of micro-millimeter stains surrounding

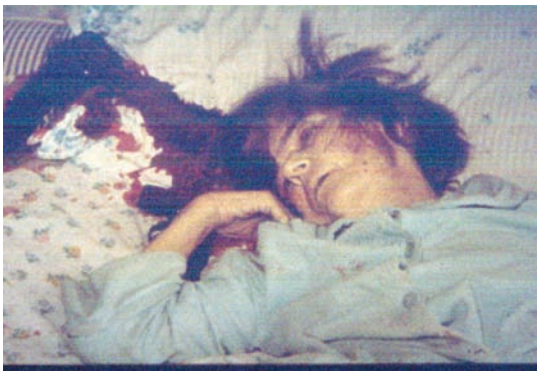

Figure 16.2 The victim of this incident died as a result of a single gunshot wound to the right temple. There was no apparent exit wound at autopsy.

Figure 16.3 This pattern was present on a nearby wall, but over six feet away from the victim. The blood present in the stain was determined to be consistent with the victim. Given the final position of the victim, the lack of an exit wound, and the atomized nature of the stains in the pattern, it is obvious the pattern could not be reconciled with the known facts.

Figure 16.4 A close-up photograph of the stain in question. The stain reflects distinct features typical of impact spatter associated with gunshot events, but also indicates some volume of blood was involved. Adding to the analyst's concern is the presence of a bullet ricochet in the pattern present on the ceiling above this pattern.

the main area of bloodstains. There was also a bullet ricochet to the right edge of the main area of bloodstains. The blood was tested and found to be consistent with the victim.

Photos, a scene diagram, and a synopsis of the facts were sent to two peers. Two different opinions were returned for consideration. One felt that an exit wound was missed at autopsy. To check this possibility the Medical Examiner's office was asked to check the x-rays for any overlooked wounds. None were found. The second peer felt that the victim was standing up in bed and the bullet fragmented upon striking the skull. To check this, the bullet extracted at autopsy was weighed and compared to the weight of a whole .38 round. The resulting information excluded this possibility.

A round-table discussion was held between the firearms examiner, bloodstain analyst, serologist, detective, and crime scene technicians to consider possible occurrences. One thought offered was that the weapon, while resting on the bed, received a volume of blood down the barrel. The gun was then held up toward the wall and fired a second time by another party.

This possibility was tested using the same weapon and ammunition. About half an eyedropper of blood was placed into the barrel and it was fired at a white cardboard target. The weapon was held approximately 18 in. away and at a 45° angle. The blood did not produce a similar pattern. In fact, very few bloodstains resulted.

During a subsequent discussion of the experiment and its result, one of the members mentioned that not all of the variables had been considered. He offered that any passage of time would congeal and thicken the blood in the barrel of the weapon. It was felt that congealing might affect the resulting stain pattern. A similar test was conducted, this time allowing the blood to set in the barrel for successive intervals of 30 min. After a cumulative period of 3.5 h the questioned pattern was replicated, complete with a bullet hole, to the edge of the main pattern area (see Figure 16.5).

Because of the effort directed at the experiment, it was later determined that the husband assisted his wife in her suicide. When placed on the bed after the suicide shot, the barrel filled with blood. This blood then congealed. The gun was left on the bed for 3.5 h, after which the husband reentered the scene and fired the gun into the wall. The combination of time, congealing, and the second shot were all factors in the ultimate pattern observed.

Figure 16.5 A photograph of the stain created during a recreation. By allowing the blood to sit and congeal in the revolver for a period of 3.5 h, the subsequent pattern produced was quite consistent with the pattern found in the scene.

Case Experiment 3 — Spatter or No Spatter

In this example the question posed was: Where would blood spatter be found on the clothing of the attacker in a beating death? An experiment was designed by the involved analyst to test the viable possibilities. A plastic motorcycle helmet with carpet padding affixed to the top and sides of the helmet was used as the model. Whole blood was poured onto the top of the carpet pad. The analyst then straddled the simulated mannequin extending from the helmet and struck the top of the helmet 10 times in succession with a flat bladed nail bar. The result produced no spatter on the shirt or shorts worn by the analyst. Thus, the experiment was utilized to show that the spatter on the suspect's clothing was not the result of beating the victim as alleged.

The cardinal rule for all experimentations is: Are the results observable, testable, and repeatable? The author was asked to evaluate the reported results. In retesting this experiment, spatter was created on both the shirt and shorts consistent with the spatter patterns found on the questioned clothing contrary to the reported results of the first analyst. This begs the question, "Why did the first experiment produce no spatter while the same experiment conducted by another analyst did?"

This required an examination of the two experiments to determine which variable had been altered to create the contradicting results. In detailed questioning of the first analyst, it was determined that after the blood was poured on the padding, some period of time passed before the simulated beating began. As a result, much of the blood introduced into the experiment ran down the hard plastic helmet and gravity pooled the rest in the lower areas on the sides of the padding. This left little blood on the top of the pad (the location of the wounds) to create spatter. As one could easily predict, if there is no blood volume at the impact site to spatter, there will be no spatter created. The variable involving the limited

volume of blood used in the first experiment was in stark contrast to the scene reality. In the case situation, as the attack continued the victim's head introduced ever-increasing volumes of blood that was available to be dispersed in the scene.

It could always be argued that, consciously or unconsciously, the experiment was designed to prove the analyst's preexisting opinion. Irrespective of how error is introduced, it is only through the ideas of the observable, testable, and repeatable practice that we are able to identify problems within experimental design and recognize conformation bias rather than objective analysis.

Experiments vs. Demonstrations

In some instances, the analyst may be asked to perform or feel that a demonstration is needed. Demonstrations can be useful, particularly when the analyst is confident of how the stains or pattern occurred, or when a specific set of circumstances is presented as the "explanation." The analyst sets about to demonstrate or show the results of the identified action. In some instances, such a demonstration or reenactment will provide investigative information. Other times it is accomplished merely as a demonstrative aid for the jury's understanding of the event. The actions undertaken to create the desired demonstration are not an "experiment." Although some analysts refer to demonstrations and specific recreations as experiments, to be an experiment there must be some form of control and at least one variable changed over the experimental run.

Summary

Experimentation is a task the analyst will likely be called upon to perform. It should not be taken lightly. The analyst should direct significant attention and effort at properly designing and performing the experiments. The goal of such experimentation is to clarify the situation by considering viable hypotheses and seeking to eliminate as many of these as possible. Ultimately, after experimentation, whatever hypotheses remain as possible must be considered against the case specifics to establish if some conclusion is possible. As with the application of scientific method in any circumstance, the analyst recognizes this conclusion is offered as the best explanation given the data.

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Dealing with the Risk of Bloodborne Pathogens

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It is imperative that analysts recognize the risk involved in processing bloodstained scenes. The very nature of the medium in which the bloodstain pattern analyst works represents a specific health hazard. Unfortunately, police organizations have been slow to develop programs to deal with this particular issue, and slower still to establish comprehensive training programs to teach effective risk management. In an informal survey in 1993, Stewart found 43 out of the 70 departments he queried without any comprehensive policy in place. Over 50 were unaware of Occupational Safety and Health Administration (OSHA) regulations governing employer responsibilities with regard to at-risk employees.[1]

In this chapter, we will discuss the basic issues and provide some limited guidelines that may assist the individual analyst or department in establishing methods for operating and managing bloodstained crime scenes.

Bloodborne Diseases

Biohazards are a concern for all crime scene personnel, but the bloodstain pattern analyst is particularly susceptible to this issue. In addition to the presence of blood, death scenes often contain urine, fecal matter, sputum, or vomit. The primary biohazards associated with such situations are HIV (human immunodeficiency virus) and hepatitis. HIV is responsible for Acquired Immune Deficiency Syndrome (AIDS). The HIV virus attacks white blood cells in the host, reducing the ability of the host to fight off other infections. For those exposed to the virus, it very often results in AIDS. The virus destroys the host's ability to fight off other microorganisms, which allows the development of various other diseases in the host.[2]

Current research indicates that HIV is transmitted only by exposure to blood, semen, vaginal secretions, or breast milk. In terms of accidental exposure (other than through consumption of breast milk or sexual contact), the nature of the exposure required is not great (e.g., contact with an open wound, needle stick injuries).

Of specific concern to the analyst is the virus' ability to survive. The HIV virus can survive outside the human body for up to 15 days in a liquid state. Dried, the virus survives for periods of 3 to 13 days, with more conservative estimates at about 3 to 5 days.[3] Temperature has a direct effect on survivability: refrigeration delays degradation of the virus, while heat speeds up its demise.[4]

The HIV transmission rate for most crime scene exposures appears relatively low. Studies suggest an infection rate of less than 1% for situations of open wounds in contact with infected blood. Mucous membrane exposure has an even lower infection rate of less than .1%. These same studies, however, suggest that the risk increases as the volume of infected blood involved in the exposure increases.[5]

Hepatitis is an additional threat present at the crime scene and of specific concern to the bloodstain pattern analyst. Hepatitis occurs in three forms: Hepatitis A (HAV), Hepatitis B (HBV), and Hepatitis C (HCV). HAV and HBV are both less severe than the

HCV form. HAV is transmitted primarily through oral or fecal routes. HBV can be transmitted through direct or indirect contact with infected blood and other body fluids. This includes needle stick injuries or other minor injuries caused by infected articles in the crime scene. In terms of the risk of infection for HBV, infected blood is more likely to result in infection than any other body fluid. HBV has the ability to survive in dried blood at room temperature for periods up to one week.[6]

Both HAV and HBV result in a variety of symptoms that affect the individual including fever, malaise, nausea, jaundice, and abdominal discomfort. If left unchecked, either form can lead to complications that are more significant or even death.[7] There are, however, preventative inoculations for both HAV and HBV. In the United States, OSHA regulations (OSHA 1910.1030) direct employers of at-risk employees to pay for such inoculations when requested by the employee.

HCV is the most severe form of hepatitis. HCV attacks the liver and leads to serious liver problems or death. There are no preventative treatments for HCV. Exposure routes for the disease are similar to HBV, with direct or indirect contact with infected blood the primary exposure risk at the crime scene. Recent studies show a less than 2% rate of infection after exposure of an open wound to HCV-infected blood, and there is an even lower incidence rate for exposure through mucous membranes. As of the date of these studies, there have been no reported cases of infection from exposure of intact skin with HCV-infected fluids.[8]

Crime Scene Considerations

As indicated, the survival of these pathogens at the scene is not an uncommon event. Therefore, those working within the scene must consider possible exposure risks and take effective measures to reduce them.

A major concern for the police or lab supervisor is whom to allow in the scene. Scene integrity considerations require that we limit the number of people who enter and move about the crime scene. The health risks imposed by such pathogens are an additional consideration that demands that we exclude all unnecessary personnel. With regard to exclusion, the supervisor must consider not only an individual's function at the scene, but also the time necessary for that individual to accomplish their task. This concern is particularly important during the collection of dried blood evidence, when the likelihood of airborne particles in the scene is temporarily high. By removing unnecessary personnel, even for a short period while the collection takes place, the supervisor effectively reduces the overall risk.

Additionally, supervisors and analysts must consider personal injuries or wounds, as both represent the single greatest source of exposure risk. Cuts, abrasions, or sores offer potential access routes for infection. Individuals with such injuries should approach the scene with extreme caution and, when practical, should avoid the scene completely. Certainly as a minimum protective measure, the individual should be using double-layer protective clothing.

The analyst should also show concern regarding preventing accidental injuries on scene. Crime scene processing and searches are filled with possible sources of injury. The analyst should move cautiously to avoid accidental needle stick injuries, cuts, or punctures from weapons, sharp-edged articles, and the like. Any accident or lapse in concentration can open the analyst to an immediate exposure risk.

As protection against these types of accidents, protective clothing for the analyst is an absolute must. Clothing concerns and solutions include double-layer techniques whenever possible. The purpose for the protective clothing is actually twofold: protection from accidental exposure at the scene, and from subsequent incidental contact with blood products tracked out of the scene. Personal protective equipment (PPE) such as disposable booties, outer garments, and gloves are the minimum requirements. Additionally, eye goggles and facemasks should be used when needed to reduce possible contact from splashes or airborne particles (e.g., during the collection of stains).

Unfortunately, methodologies clash in this regard. One of the primary methods of collecting dried bloodstains for DNA analysis is by scraping and collecting the entire stain. This increases the overall risk to the collector, as small particles will flake off and often become airborne. Such particles can be ingested, breathed in, or make contact with the eyes. Until procedures change, analysts should remain cognizant of the increased risk and take some action to protect themselves.

We should also consider the personal actions of officers and analysts at the scene. Eating, drinking, smoking, and the application of cosmetics while in the crime scene are all considered risky behavior and should be prohibited.[9]

A final concern in terms of exposure risk is post-processing exposure through contamination of crime scene equipment and clothing. The use of PPE while in the scene, including shoe booties, is critical. Booties prevent analysts from carrying contaminants to their home, office, or car on their footwear. Durable personal items such as the analyst's favorite pen or notebook should not be utilized inside the scene. It is better to use disposable pens and paper pads. When processing is complete, these items are disposed of, thereby eliminating any possible contamination issues. Durable crime scene equipment exposed to biohazards in the scene can be decontaminated. Durable equipment should be washed with a 1:10 dilution of bleach and water. Items such as plastic photo tents or scales can be cleaned with less caustic commercial alcohol solutions.

Supervisors should always establish a biohazard collection point at the working perimeter. The collection point should have large plastic trash bags taped open. This helps eliminate excessive handling of contaminated items by crime scene technicians. New PPE should be present here, making it easy for technicians to change gloves and booties when exiting and reentering the scene. Generally, a local hospital can deal with the small amount of biohazard materials collected during crime scene processing, but we suggest coordinating such support before the need arises.

Dealing with Accidental Exposures

No one can guarantee a method of dealing with accidental exposure that will effectively eliminate the risks involved. We offer the following guidelines as a basic response to accidental exposure.

Crime scene supervisors should always consider exposure prevention as their primary strategy for protecting their workers. The next step in prevention is vaccination against HBV. Any technician who works in biohazard scenes should be vaccinated. If prevention fails, the exposed individual should seek medical assistance in order to obtain treatment. CDC research indicates that timely reporting is important and treatment should be sought in hours not days.[10]

Current guidelines for on-scene first aid include:

- For situations of simple contact, wash the area involved with soap and water or an antimicrobial wash.
- Exposed mucus membrane tissues should be flushed with water.
- Although prior guidelines suggest allowing needle stick injuries and other wounds to bleed freely for a moment, there is no evidence to suggest this action will reduce the probability of infection.[11] If possible, wash and rinse the wound with soap and water or an antimicrobial solution. The injured party should then seek medical assistance and report the incident to supervisors.

Packaging Biohazard Evidence

Proper packaging of serologic evidence ensures that no loss of evidence occurs. Proper packaging also effectively eliminates subsequent contamination risks to those who must handle the evidence.

Methodologies for packaging present a contradiction. Clothing and other bloodstained items are generally packaged in paper products to ensure the samples do not degrade. If packaged in this fashion at the crime scene prior to complete drying, blood can seep through the paper.

Because of concerns over exposure to biohazard materials, authors such as Bigbee suggest returning to plastic packaging. However, plastic means the increased possibility of degraded samples, which is also unacceptable. One consideration is to package the wet items in paper at the scene and then containerize them in plastic until they can be returned to an appropriate facility. There they can be dried and repackaged. In the end, the analyst or police department must consider both the evidential considerations and exposure risks, and then develop a packaging policy that best fits their organizational needs.

Whatever methods are used for packaging, ensure that containers allow some level of assurance to those opening them at the crime lab that the exposure risk is minimal. Double packaging of inner containers and the proper labeling of outer containers prevent surprises to those who may need to handle the evidence at a later date.

Exposure Risks in Training and Experimentation

Exposure risks are not limited to crime scenes. Those involved in training, those attending training classes, and those conducting experimentation should avoid unnecessary exposure. Although most blood used for this purpose comes from blood banks, the analyst should apply universal precautions and consider all products contaminated.

A development in training is the use of animal blood as a substitute for human blood during training courses. Christman presented an interesting study to the International Association of Bloodstain Pattern Analysts in which he compared different types of animal blood. Neither the HIV nor HBV virus is transmitted through animals such as horses, cows, and sheep. Although such animals may harbor other pathogens (e.g., brucellosis), these pathogens do not represent the level of risk associated with human blood. For this

reason, Christman feels these sources may be very appropriate for use in training police and others in the discipline of bloodstain pattern analysis.[12]

Other Sources of Information on Managing Bloodborne Pathogen Risks

The discussion of the problems and issues related to bloodborne pathogens in this chapter is very general. In seeking to establish a comprehensive risk management policy, there are several documents that provide a more in-depth discussion of the subject. We suggest seeking out all of them for further guidance. One of the best documents available for the individual analyst is David Bigbee's manual entitled *The Law Enforcement Officer and AIDS,* which is available through the U.S. Government Printing Office. Other documents that may be of assistance in establishing a pathogen risk management policy include:

A Curriculum Guide for Public Safety and Emergency Response Workers, published by the Centers For Disease Control.
AIDS and the Law Enforcement Officer: Concerns and Policy Responses, published by the National Institute of Justice.
OSHA Regulation 1910.1030 — Bloodborne Pathogens.[13]

Summary

The danger that law enforcement personnel and analysts face from bloodstained scenes is not likely to be eliminated in the near future. Processing the scene demands that someone come in contact with the evidence, and contact means an exposure risk. It is imperative, then, that both analysts and supervisors recognize this danger and introduce steps to reduce the risk. The only rational means of dealing with this problem is to take proactive measures as part of a comprehensive risk management policy; business as usual in the crime scene is no longer a viable option.

Research on the treatment of individuals exposed to the various bloodborne pathogens is ongoing. As a result of this effort, methods and guidelines are likely to change. The best advice we can provide the analyst or supervisor is to remain vigilant in reducing accidental exposure risks. A few simple steps, a little education, and the purchase of basic protective gear will effectively eliminate the majority of accidental exposures. The prevention of exposure is always preferred over treatment of individuals for exposure, not only in terms of the well-being of employees, but also from a financial standpoint. When and if prevention fails, pattern any treatment plan on the advice of health care professionals.

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Weight/Measurement Conversion Table (Approximations)

To Convert	Multiply by	To Get	Symbol
	Linear Measure		
Inches	25.4	Millimeter	mm
Millimeter	.04	Inches	in.
Inches	2.54	Centimeter	cm
Centimeter	.4	Inches	in.
Feet	30.48	Centimeter	cm
Centimeter	.033	Feet	ft
Feet	.33	Meter	m
Meter	3.3	Feet	ft
Yards	.91	Meter	m
Meter	1.09	Yards	yd
	Liquid Measure		
Fluid Ounce	30	Milliliters	ml
Milliliter	.03	Fluid Ounce	fl. oz.
Quart	.95	Liter	l
Liter	1.06	Quart	qt
Gallon	3.8	Liter	l
Liter	.26	Gallon	gal
Milliliter	1000	Microliter	µl
Microliter	.001	Milliliter	ml
	Weight		
Ounce	28	Gram	g
Gram	.035	Ounce	oz
Pound	.45	Kilogram	kg
Kilogram	2.2	Pound	lb
	Metric Unit Equivalents		
Unit	Number of Units		
Meter/Gram/Liter	1	one	
Deci	.10	one tenth	
Centi	.01	one hundredth	
Milli	.001	one thousandth	
Micro	.000001	one millionth	

Trigonometric Functions and Their Application in Bloodstain Pattern Analysis

Mathematics by definition is the systematic treatment of magnitude, relationships between figures and forms, and relationships between quantities expressed symbolically.[1] Mathematics allows us to recognize relationships in real objects in order that we may better understand them.

Bloodstain pattern analysis draws on mathematics in several areas that were outlined in Chapter 6. In particular, the analyst uses the trigonometric functions. These functions define the relationships between the internal angles that comprise a triangle and the length of its sides. Although the analyst may not fully appreciate these relationships, their specific application to our discipline is relatively easy to understand.

Here we consider only the trigonometric functions related to the right triangle and not those that define the plain triangle. The latter may be of some interest to the analyst, however, as authors have described methods by which the analyst can determine a convergence point using these relationships.[2] These methods are generally used in the algorithms of software designed to determine point of convergence.

To consider properly the trigonometric functions, the analyst must first understand four terms and accept two basic facts true to all triangles. The terms of importance are:

- **Right triangle**: A triangle in which one of the three angles measures 90°. In Figure B.1, the angle at A is a 90° angle, making the triangle a right triangle.
- **Hypotenuse**: This term designates the side of the triangle opposite the 90° angle. In the figure the side labeled a is the hypotenuse.
- **Side opposite**: This term designates the side of a triangle opposite a given angle. The side labeled c is the side opposite angle C.
- **Side adjacent**: This term designates the side of the triangle adjacent to a given angle, but not the hypotenuse. The side labeled b is the side adjacent to the angle C.

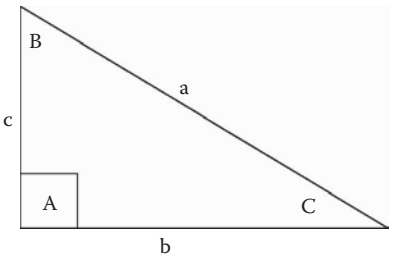

Figure B.1 A right triangle is any triangle in which one angle measures 90°. In this figure, angle A is 90°.

Table B.1 Trigonometric Function Table

Angle	sin	tan	sec	csc	ctn	cos	
0°	0.000	1.000				1.000	90°
5°	0.087	0.087	1.004	11.474	11.430	0.996	85°
10°	0.174	0.176	1.015	5.759	5.671	0.985	80°
15°	0.259	0.268	1.035	3.864	3.732	0.966	75°
20°	0.342	0.364	1.064	2.924	2.747	0.940	70°
25°	0.423	0.466	1.103	2.366	2.145	0.906	65°
30°	0.500	0.577	1.155	2.000	1.732	0.866	60°
35°	0.574	0.700	1.221	1.743	1.428	0.819	55°
40°	0.643	0.839	1.305	1.556	1.192	0.766	50°
45°	0.707	1.000	1.414	1.414	1.000	0.707	45°
	cos	ctn	csc	sec	tan	sin	Angle

The two basic facts that assist us in understanding the application of the trigonometric functions are:

- For any triangle, the sum of the three internal angles is always 180°.
- For every combination possible for these three angles, there is a distinct ratio between the angles and the lengths of the sides of the triangle.

The relationships of concern to the analyst are known as the sine and tangent. Based on these two functions, we know that for any value of angle C in Figure B.1, the following is true:

$$\sin C = \frac{\text{opposite}}{\text{hypotenuse}} \quad \text{or} \quad \frac{c}{a}$$

$$\tan C = \frac{\text{opposite}}{\text{adjacent}} \quad \text{or} \quad \frac{c}{b}$$

These ratios are displayed in a trigonometric function table. Generally, such a table shows the ratios for every angle between 0 and 90°, in increments of at least 1°. If you recall the discussion on determining the impact angle, that level of detail is unnecessary. The impact angle determination is generally accurate only to about 3°. Table B.1 is an abbreviated trigonometric function table, in increments of 5°.

Let us begin with the sine function, which helps establish the angle of impact for a given droplet. In Figure B.2, note that the orientation of the right triangle is rotated. The right angle is now at the top of the triangle.

Given our discussions in Chapter 4 and considering Figure B.2, we should feel confident that:

- The droplet in flight is generally spheroid in shape.
- Therefore, any measurement of the diameter of the droplet will be equal. Thus, in the figure, AB = DE.

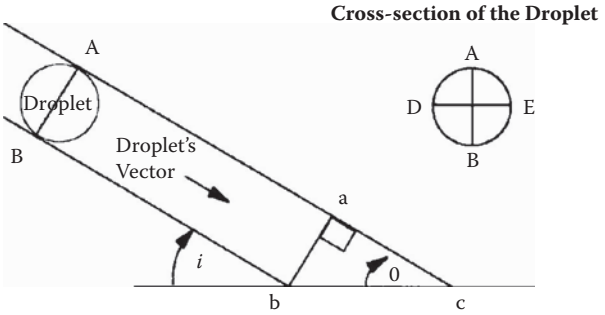

Figure B.2 The path at which a droplet strikes a target in combination with the target defines the right triangle abc. Using this triangle, we can draw an analogy between the dimensions of the resulting stain and the triangle, which allows the analyst to define the impact angle.

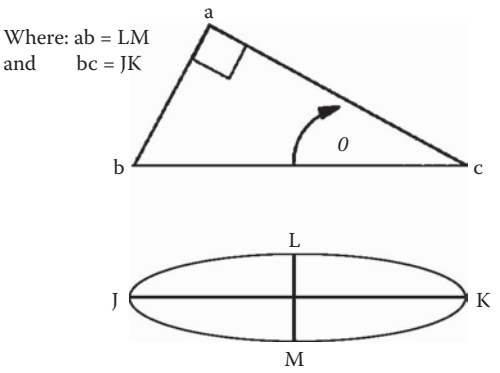

Figure B.3 The relationship we draw between the resulting stain and the right triangle. The side opposite (line ab) is analogous to the width of the stain (line LM). The hypotenuse (line bc) is analogous to the length (line JK).

In Figure B.2, the triangle we will use to solve the problem is formed by the vertical dimension of our droplet (line ab), the path of the droplet (line ac), and the area on the target surface between the point where the droplet first touches and the termination of the path (line bc). Also note that when viewing Figure B.2, angle *i* is the same as angle 0. Angle *i* defines the impact angle and is what we seek to determine.

In Figure B.3, we transpose the triangle and now compare it to the resulting stain. We can draw an analogy between the length of the hypotenuse (bc) and the length of our stain (JK), and another between the width element of the stain (LM) and the side adjacent (ab). Using the measurements of JK and LM in the stain, we can define the angle 0, where:

$$\sin 0 = \frac{\text{opposite}}{\text{hypotenuse}} \quad \text{or} \quad \frac{ab}{bc} \quad \text{or} \quad \frac{lm}{jk}$$

The result of this division is a ratio. The analyst then finds this ratio in the trigonometric function table and identifies the closest corresponding angle. If the analyst has a scientific calculator, the inverse sine of 0 or arc sine function (ASN), which converts this ratio to the angle, can also be used.

One important note: in viewing the diagrams, it may appear that a 1:1 relationship exists between line LM and line ab or between line JK and line bc. This isn't true. As the

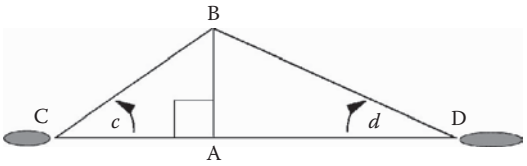

Figure B.4 The relationships of our scene to another right triangle when using the tangent formula. The probable point above the target where the stain originated is defined by the line AB. The line AC is equal to the distance from the base of Stain C to the point of convergence (A). The angle c is the impact angle for Stain C.

droplet impacts, the liquid laterally displaces outward. So the droplet's diameter in flight is much smaller than the resulting stain width; however, because this displacement occurs in both the length and width axes of the resulting stain, it has no effect on the application of the trigonometric functions.

Our application of the tangent function is a little more direct. (Refer to Figure B.4.) Given several droplets that impact a surface as a result of a single event, we may want to define the point of their origin (B). To do this we need to determine the length of the side opposite the two angles c and d, which is line AB. In the figure, line AC is the side adjacent to the angle c and line AD is the side adjacent to the angle d. Because AB is simply a straight line projected from the unknown point of origin to the target surface, the angle at A for both triangles is a right angle.

If we wish to solve for the angle c in Figure B.4, the tangent function tells us that for every right triangle:

$$\tan C = \frac{\text{opposite}}{\text{adjacent}} \quad \text{or} \quad \frac{AB}{AC}$$

We can easily determine the two impact angles (c or d) using the sine function. By measuring from the base of each stain to the point where their paths intersect, we can also determine the length of the adjacent side of each triangle. Using these two known values, we solve for the unknown length of the side opposite (line AB) by balancing the original equation. For the triangle ABC and the angle c, that means:

$$\text{side opposite} = \tan C \cdot \text{side adjacent}$$

or

$$AB = \tan C \cdot AC$$

Considering the triangle created by each droplet's impact, we can establish a general distance above the target surface for Point B. If all of the droplets are from the same origin and event, then this distance should be the same. To understand the limitations of the tangent relationship in defining the point of origin, review the discussion in Chapter 6.

Accuracy, Precision, and Significant Digits

No matter what we choose to measure — bloodstains, football fields, or our own height — there is always a level of uncertainty in any measurement process. The nature of the

uncertainty is affected by two concepts: accuracy and precision. Accuracy in a measurement is a statement as to the level of certainty the measurer has for the final measurement. The greater the level of uncertainty in the measurement, the lower the accuracy. Precision, on the other hand, describes the ability of the analyst to repeat the measurement. The more likely it is that the measurement can be repeated, achieving the same result, the higher the level of precision. Accuracy is affected most by the nature of the thing being measured, whereas precision is affected most by the method of measurement employed.

In considering the determination of droplet impact angles using the formulas discussed, accuracy and precision both affect the level of trust the analyst has in the resulting impact angle. In terms of accuracy, it should be self-evident that because we apply straight-line geometry to define an angle that is created by a parabola, the level of accuracy is not great. It is not so much the precision of the measurements used by the analyst, but rather the manner of measurement and the nature of the thing (the impact angle) being measured. We generally accept that impact angles are accurate to ±3° for drops impacting at 60 degrees or less.

Precision in measuring the bloodstain is also a factor. Remember, precision speaks to the ability to repeat the measurement and achieve the same result (the same measurement). The manner of measuring the stain is critical in defining precision. For instance, if the analyst uses a ruler scaled to 1 mm to measure small bloodstains, then precision will likely suffer. In viewing such a scale in relation to the stain, the analyst is estimating the final digit of the measurement down to the nearest 0.5 mm. On the other hand, should the analyst use a micrometer, scaled to the nearest 0.1 mm, precision of the measurement increases. Now, the analyst is estimating the final digit for the measurement down to the 0.05 mm level. Just as important to the precision of the measurement is the knowledge or skill of the measurer. As discussed in Chapter 6, if the analyst inappropriately includes portions of the tail or scallops in the measurement, precision of the measurement will suffer.

The result of any impact angle or point of origin determination will ultimately be given as a measurement, either as an angle of impact (e.g., 65°) or a distance from a target (e.g., 2.5 ft). In accepting this measurement, the analyst must recognize the significant digits in the result. This significant digit is always the estimated digit. For instance, given an impact angle determination of 64.5°, the analyst cannot assume the significant digit is 5. The uncertainty present in the accuracy component (±3°) tells us the answer is estimated to the second digit (e.g., 4). Recognition of the significant digit in an equation's answer is recognition of the overall uncertainty of the answer itself. To be objective, analysts must keep in mind the effects of accuracy and precision on the measurements, and then represent their investigative findings appropriately. This means keeping an eye on the significant digit, and not alluding to a level of certainty that does not exist.

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Bloodstain Classification Decision Map

Primary stains Are Spatter?

Y

N

Group B
1. Primary/parent stains are other than small elliptical and circular shaped stains.
Note: This classification does not preclude the presence of spatter associated to the primary stain (e.g. gush or blood into blood).

Non-spatter

Irregular Margin?

Y

N

Group B 1
1. Non-spatter stain
2. Irregular margin

Irregular Non-Spatter

Numerous Associated Spatter or spines?

Y

N

Group B 1.1
1. Non-spatter stain
2. Irregular margin
3. Spatter/Spines.

Random oriented spatter on margin?

Y

N

Group B 1.1.1
1. Non-spatter stain
2. Volume accumulation
3. Irregular margin
4. Random spatter around the margin.

Blood into Blood

Group B 1.1.2
1. Non-spatter stain
2. Volume accumulation
3. Irregular margin
4. Spines around the margin.

Gush/Splash

Group B 1.2
1. Non-spatter stain
2. Irregular margin
3. No spatter/spines.

Smear

Pre-existing Stain?

Y

N

Group B 1.2.1
1. Non-spatter stain
2. Irregular margin
3. No spatter/spines
4. Pre-existing stain.

Wipe

Group B 1.1.2
1. Non-spatter stain
2. No volume accumulation
3. No recognizable pattern
4. No pre-existing stain.

Swipe

Group B 2
1. Non-spatter stain
2. Regular margin

Regular Non-Spatter

Patterned Deposit?

N

Y

Group B 2.1
1. Non-spatter stain
2. Regular margin
3. Recognizable pattern.

Pattern Transfer

Group B 2.2
1. Non-spatter stain
2. Regular margin
3. No patterned deposit

Absorbed Into surface

Y

N

Group B 2.2.1
1. Non-spatter stain
2. Regular margin
3. No patterned deposit
4. Absorbed into surface

Saturation

Group B 2.2.2
1. Non-spatter stain
2. Regular margin
3. No patterned deposit
4. Not absorbed

Movement w/surface contours

Y

N

Group B 2.2.2.1
1. Non-spatter stain
2. Volume accumulation
3. Regular margin
4. Movement with surface contours

Flow

Group B 2.2.2.2
1. Non-spatter stain
2. Volume accumulation
3. Regular margin
4. No movement with surface contours

Pool

Group A
1. Primary stains are droplet(s) (circular and shaped stains)

Spatter

Linear curvilinear?

Y

Group A 1
1. Spatter.
2. Arranged in linear orientation

Linear Spatter

Volume in individual stains?

Y

Group A 1.1
1. Spatter.
2. Linear orientation.
3. With volume in ind. stains.

Spurts

N

Group A 1.2
1. Spatter.
2. Linear orientation.
3. No evident flows in ind. stains.

Progressive Change in Shape?

Y

Group A 1.2.1
1. Spatter.
2. Linear orientation.
3. With no evident flows in ind. stains
4. Progressive consistent impact angle change.

Cast-off

N

Group A 1.2.2
1. Spatter.
2. Linear orientation.
3. No evident flows in ind. stains.
4. No progressive impact angle change.

Drip Tail

N

Group A 2
1. Spatter
2. No linear orientation

Non-linear Spatter

Is there a radiating distribution?

Y

Group A 2.1
1. Spatter
2. No linear orientation
3. The pattern does have a Radiating distribution.

Impact-Spatter

Ringlets or Vacuales?

Y

Group A 2.1.1
1. Spatter
2. No linear orientation
3. The pattern has a radiating Distribution
4. Ringflats or vacuales

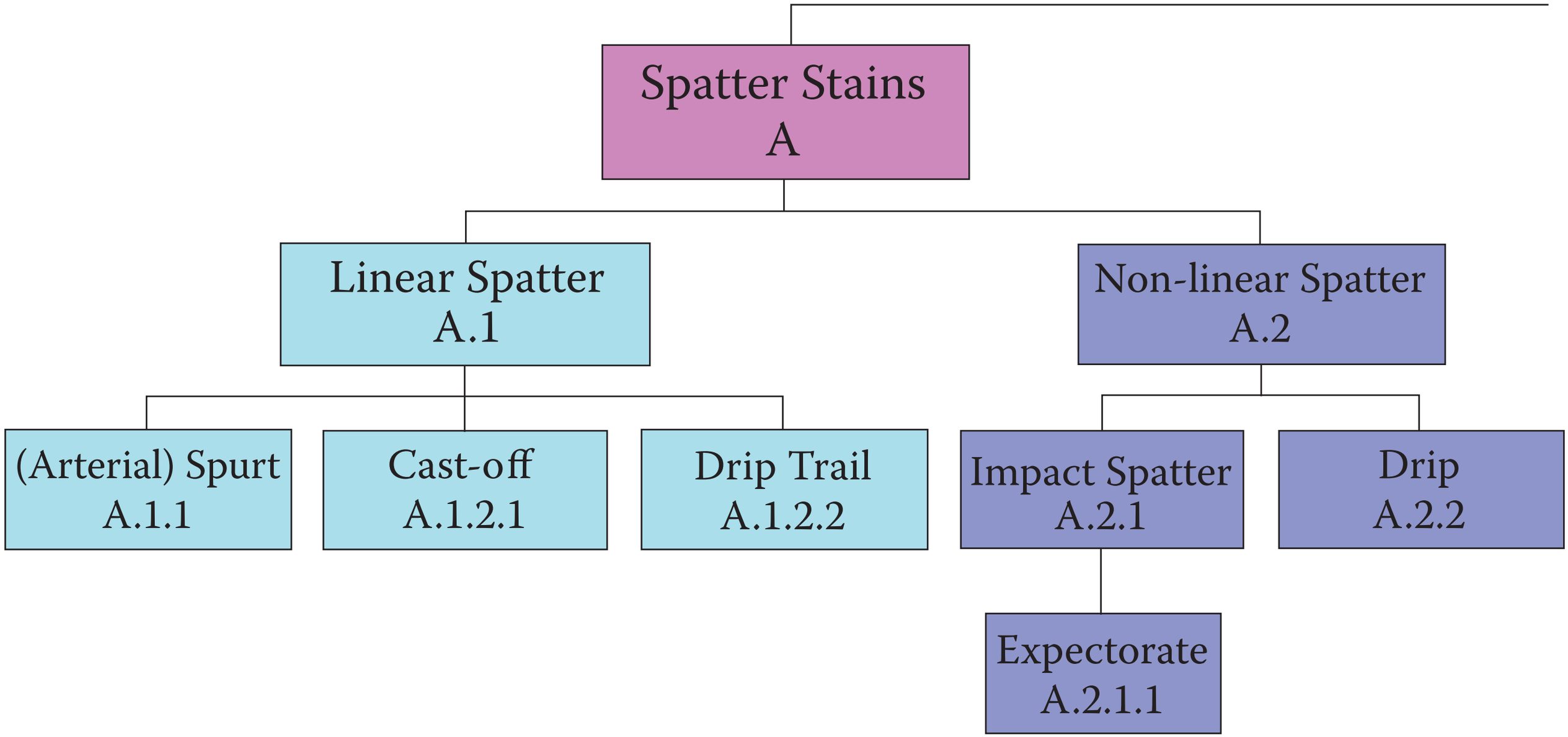
Expectorate

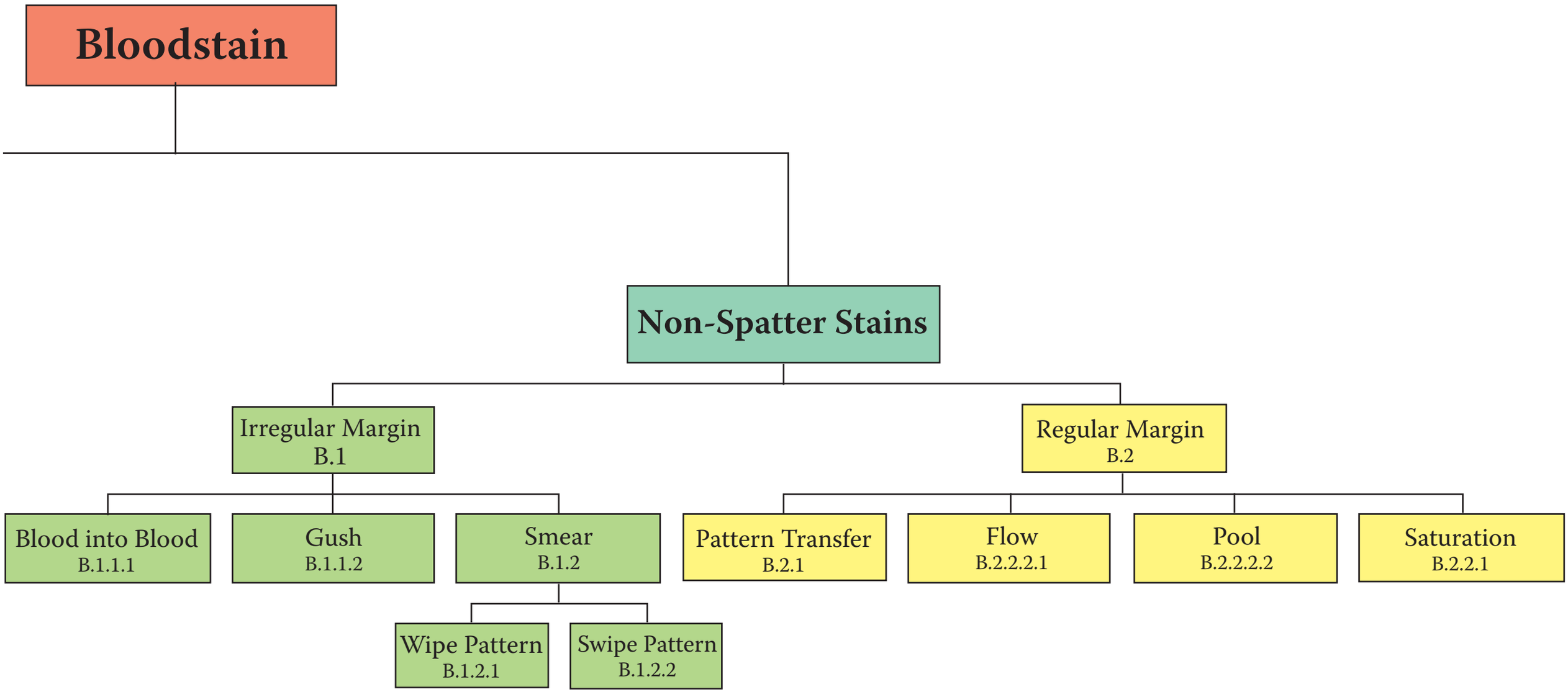
N

Group A 2.2
1. Spatter
2. No linear orientation
3. There is a random distribution And no radiating pattern.

Drip

Bloodstain Classification Taxonomy




Bloodstain
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Regular Margin
B.2
Blood into Blood
B.1.1.1
Gush
B.1.1.2
Smear
B.1.2
Pattern Transfer
B.2.1
Flow
B.2.2.2.1
Pool
B.2.2.2.2
Saturation
B.2.2.1
Wipe Pattern
B.1.2.1
Swipe Pattern
B.1.2.2

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