Bloodstain Pattern Analysis

With an Introduction to Crime Scene Reconstruction

Tom Bevel
Ross M. Gardner

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Bloodstain Pattern Analysis Second Edition

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CRC PRESS

Boca Raton London New York Washington, D.C.

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Library of Congress Cataloging-in-Publication Data

Bevel, Tom
Bloodstain pattern analysis : with an introduction to crime scene reconstruction / Tom Bevel, Ross M. Gardner.--2nd ed.
p. cm. -- (CRC series in practical aspects of criminal and forensic investigations)
Includes bibliographical references and index.
ISBN 0-8493-0950-6 (alk. paper)
1. Bloodstains. 2. Forensic hematology. 3. Crime scene searches. I. Gardner, Ross M. II. Title. III. Series.

HV8077.5.B56 2001
363.25′62--dc21 2001035882

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No claim to original U.S. Government works
International Standard Book Number 0-8493-0950-6
Library of Congress Card Number 2001035882
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0
Printed on acid-free paper

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Foreword

Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction, Second Edition, is a very clearly and concisely written text. In fact, it is the most complete and comprehensive handbook to date from the perspective of the investigator on the subject of bloodstain spatter analysis.

The authors have provided the reader with an articulate and practical guide to the interpretation of bloodstain patterns and crime scene analysis reconstruction. This second edition text has become the basis for standardization of blood spatter analysis. *Bloodstain Pattern Analysis: With an Introduction to Crime Scene Reconstruction* has heightened 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.

The text provides specific details on crime scene analysis and reconstruction in explaining the scientific methodology involved in the process. The authors provide an excellent historical perspective to acquaint the reader with the significant chronology of the application of this technique. The authors also provide excellent information on distinguishing crime scene analysis from behavioral analysis and discuss the considerations involved in the reconstruction of the crime. There is an entire chapter dedicated to the important subject of proper terminology to be utilized in these analyses. *Bloodstain Pattern Analysis* explains the complex mechanics of blood spatter analysis with chapters that address the dynamics of reconstruction, such as determining motion and directionality, convergence and the point of origin, evaluating impact spatter bloodstains, the characteristic patterns of blood which aid in analysis and the proper documentation of blood stains and the reconstruction of a crime. The authors have included two chapters on software applications and demonstrative evidence for court presentation. Most significant in the Second Edition is the addition of over 100 photographs, which graphically illustrate the dynamics of bloodstain patterns, practical applications, case histories and excellent appendices.

The authors bring over 50 years of practical experience to this text. Tom Bevel, my friend and colleague for many years, is a retired police Captain from Oklahoma City, Oklahoma. Bevel is the owner of TBI, a forensic edu-

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cation and consulting company. He is also an associate 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. Bevel has numerous professional affiliations and has acted as a police consultant in over 41 different states and 8 foreign countries. He has personally participated in over 3000 criminal investigations in which bloodstain spatter evidence was the issue and has testified in numerous trials as an expert witness.

Ross Gardner served for The United States Army Criminal Investigation Command (USACIDC) for over 24 years as a felony criminal investigator and is now the Chief of Police for a small suburban Atlanta Police Department. 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 is a consultant in crime scene analysis, bloodstain pattern analysis, and crime scene investigation also has numerous professional affiliations. Gardner has qualified as an expert in bloodstain pattern analysis and crime scene reconstruction in both state and federal courts.

In my textbook *Practical Homicide Investigation: Tactics, Procedures, and Forensic Techniques, Third Edition*, I point out that, "Solving homicides, especially those without witnesses, is 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 interpretation 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 the 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 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, Second Edition is a masterful blend of practical scene knowledge

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and the application of scientific methodology to the process of crime scene reconstruction. It is organized in such a manner to allow the reader quick and easy reference into specific areas of blood spatter.

Vernon J. Geberth, M.S., M.P.S.
Series Editor

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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. The task is anything but simple and the tools employed are all of the forensic disciplines.

Each area of forensics provides insight and a glimpse 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 information as to the "who" of crime. Fingerprints, serology, and trace and fiber evidence allow the analyst to associate people or objects with a crime scene. Forensic pathology, on the other hand, has always been the 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 has certainly reawakened to its role in modern forensics as another method of illuminating the "what" of crime. Used properly, it 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, leading 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 from two distinctly different backgrounds, although 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

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city of London, at the Metropolitan Police Detective Training School. There both authors, although several years apart, attended the Scenes of Crime Officer (SOCO) course.

The English approach to crime scenes, at the very least, is one of the most methodical in the world. The SOCO course teaches students to understand and incorporate all forensic evidence in the evaluation of a 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 on proper crime scene analysis. However, case resolution is not just a matter of proving someone guilty. The investigator seeks 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.

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 positions and attempt to diminish that which works against them.

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 one is 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. That cannot, however, lead to an expectation that the bloodstain evidence will stand alone. In the right hands, however, bloodstain pattern analysis is an extremely effective tool for defining the truth.

Bloodstain pattern analysis is not for the casual investigator, who intends only to graze the surface, find a quick answer, and move on. The bloodstain

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pattern analyst is truly one who reconstructs crime scenes. As such, he or she must understand all 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 this fashion, the *evidence* establishes a knowledge base from which the analyst reaches the "truth."

In part, the oath of office for a U.S. Army Criminal Investigation Special Agent states: "*I shall at all times seek diligently to discover the truth, deterred neither by fear nor prejudice…*" We dedicate this book to the men and women, analysts and investigators alike, who recognize and understand the importance of their roles as objective truth seekers.

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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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Acknowledgments

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

Rudi Jaehser of Frankfurt, Germany, for his untiring efforts in leading Ross through the bowels of the Frankfurt University library those many late evenings.

Regina Dearborn, for her expert translations of many of the articles discussed in Chapter 2. Without her skill in German and her ability as a legal translator many of these articles would have remained unknown.

Toby Wolson of Miami, Florida, for his support in providing excellent examples of the roadmapping concept.

Sgt. Ron Wortham with the Oklahoma City Police Department, who designed and constructed equipment used in bloodstain pattern research, the results of which appear in this text.

Jouni Kiviranta of the Helsinki Police, whose outstanding photography skills produced many of the enclosed figures.

Dr. Martin Fackler of Florida, for his support and critical eye. Dr. Fackler readily shared his knowledge and research with us, providing important information for Chapter 7.

Leonard Conn, formerly with the University of Oklahoma Police Department, who assisted in building equipment for both the stop-motion photography of blood impacting at various angles and the high-speed photographs of a bullet impact into a bloody target. Examples of both are included in this book.

Vernon Geberth, who believed in our ability and helped bring the project to fruition. Without his support the book would still be a dream.

Victoria Miller of Miller Forensic Computing, for her unselfish loan of a full-function copy of *No More Strings III*© for a separate project. Her help and support ultimately led to the inclusion of many critical parts of Chapter 6.

Dr. Alfred Carter of Carleton University, Ottawa, for remaining patient and calm in the face of Ross' repetitive need for physics instruction and for his permission to use images from the FCO software *Backtrack Images*®, *TRACKS*®, and *Backtrack/Win*®. A special thanks goes out to Dr. Carter for no reason other than no other single scientist or member of academia has given as much to this discipline as he has.

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Dr. Kenneth Beard of Urbana-Champaign, Illinois, whose original research led to our 5-year search to better understand droplet impacts. Much of our understanding from Chapter 4 would not exist without Dr. Beard's initial assistance.

Don Coffey of the U.S. Army Criminal Investigation Command, for sharing his approach and knowledge on dealing with pattern transfers.

John Anderson, Sheriff of El Paso County, Colorado, for his untiring support and friendship. Whenever the project took a detour or seemed off track, John would offer a word of encouragement or support. Finally, he reminded us that nothing good is ever gained without some level of risk.

Dr. Ronald O. Gilcher, M.D., and Arlene Wilson with the Oklahoma Blood Institute, who over many years have provided much information about blood components and the processing involved in blood products provided for research.

The members of the Metropolitan Police Forensic Crime Laboratory, London, England, who allowed us to use still images from their outstanding video "Blood in Slow Motion."

To all the students from the basic bloodstain pattern schools conducted by Tom and Ross. Their constant demand for more and more knowledge causes their teachers to continue to grow within this discipline. The same is true of all of the students of the Basic Crime Scene Reconstruction course. From each and every class we have gained knowledge and learned new techniques.

Lt. Travis Witcher (Ret.) of the Oklahoma City Police Department, for securing funding from outside sources that allowed Tom to attend training under MacDonell and Bunker and at Hendon Police College in England. Lt. Witcher required at the end of this training that Tom start his own research and training to pass on the knowledge gained to OCPD officers. We can all benefit from the insight in his comment, "Teaching will force you to really learn the discipline." His wisdom is more than evident and serves as a challenge for each of us.

William Turner, formerly of the USACIDC, who sparked a flame in Ross by sharing the knowledge he gained from a Corning Institute bloodstain pattern course. Bill probably has no idea of the events he set in motion, but we thank him anyway.

The many instructors of the Scenes of Crime Officer course, Metropolitan Police Detective Training School, Hendon, England. Their insight and knowledge are responsible in large part for forging Tom and Ross' shared passion.

Three units of the Oklahoma City Police Department and their respective members through the years: Technical Investigations, the Forensic Lab, and Homicide. All of them helped focus this discipline and develop Tom's "scene sense." Thank you for your never-ending support.

Scott Hector, whose computer and late night efforts helped create many of the illustrations/figures used in the book.

The following agencies and individuals, for supplying various photographs in support of the project: Henry Muse, E-Systems; Lt. William D. Gifford, Anchorage Police Department; Donald R. Schuessler, Department of Public

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Safety, Eugene, Oregon; Tom J. Griffin and Barie Goetz, Colorado Bureau of Investigation; John Graham, Arvada Police Department, Colorado; Helena Komuleinen, curator of the Finnish National Gallery; Lt. Johnny Kuhlman, Oklahoma City Police Department; the Edmond Police Department, Oklahoma; Doug Perkins, Oklahoma State Bureau of Investigation; Ray Clark, Oklahoma City Police Department; Heikke Majamma, National Bureau of Investigation, Helsinki, Finland; Peter Barnett; Dr. Daniel Davis; *The Journal of Forensic Identification*; Mark Nelson, Springdale Police Department, Arkansas; T. Daniel Gilliam, Larimer County Sheriff's Department, Fort Collins, Colorado; David Stiles, Texarkana Police Department, Arkansas; Louis Laurel, State of Texas Attorney General's Office; Don Blake and Bill May, Norman Police Department, Oklahoma; Mike McGuffey, Covington Police Department, Kentucky; Claire Dawnson-Brown, Travis County District Attorney's Office, Texas; Iris Dalley, OSBI, Oklahoma City, OK; Steve Chancellor, USACIDC; Sandra M. Roberts, Eugene Police Department, Oregon; David Stiles, Texarkana, Arkansas.

The International Association of Bloodstain Pattern Analysts, the Rocky Mountain Association of Bloodstain Pattern Analysts, and the Association for Crime Scene Reconstruction, for establishing an environment in which we can all grow.

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 efforts, insight, and resulting research in support of bloodstain pattern analysis and crime scene reconstruction.

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The Authors

Captain Tom Bevel (Ret.) is the owner of TBI, a forensic education and consulting company. He is also an associate professor in the Masters of Forensic Science program at the University of Central Oklahoma, Edmond, Oklahoma. He retired after 27 years with the Oklahoma City Police Department. His last assignment was the Commander of the Homicide, Robbery, Missing Persons, and the Unsolved Homicide units.

Captain Bevel holds a Master of Arts degree in Administration of Criminal Justice from the University of Central Oklahoma. He is a graduate of the Scenes of Crime Officer course, Hendon, England; the Technical Investigations course, Central U.S. Police Institute, Oklahoma State University at Oklahoma City; the FBI National Academy; and the Post-Graduate Medical-Legal course, London Medical College, London, England.

Captain Bevel is a Fellow of the Association for Crime Scene Reconstruction (ACSR) and the American College of Forensic Analysts; a Distinguished Member of the International Association of Bloodstain Pattern Analysts (IABPA); a Regional Representative for the International Association for Identification (IAI); a member of the Editorial Board for the *Journal of Forensic Identification*; and a member of the Southwestern Association of Forensic Scientists (SWAFS) and the American Academy of Forensic Sciences (AAFS).

Captain Bevel has served as a crime scene consultant in more than 41 U.S. states and 8 foreign countries. He has been qualified as an expert in crime scene reconstruction and bloodstain pattern analysis in both state and federal courts.

Special Agent Ross M. Gardner (Ret.) worked for the U.S. Army Criminal Investigation Command (USACIDC) as a felony criminal investigator for more than 20 years. He retired as a Command Sergeant Major and Special Agent in 1999 after serving in U.S. Army law enforcement for more than 24 years and is now the Chief of Police of a small suburban Atlanta police department.

Special Agent Gardner holds a Master's degree in Computer and Information Systems Management from Webster University, a Bachelor's degree in Criminal Justice from Wayland Baptist University, and an Associate's

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degree in Police Science from Central Texas College. He graduated first in his class at the Scenes of Crime Officer course, New Scotland Yard, Hendon, England. From 1988 to 1996 he served as an adjunct professor of the police science program at Central Texas College. He is a 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 the Chairman of the Education Committee for both the RMABPA and the International Association of Bloodstain Pattern Analysts (IABPA).

Special Agent Gardner is certified by the International Association for Identification (IAI) as a Senior Crime Scene Analyst, a rating he has held for 10 years. He is an active instructor and consultant throughout the United States in crime scene analysis, bloodstain pattern analysis, and crime scene investigation, teaching to a variety of groups, from police and investigative organizations to trial counsel professional development groups. Special Agent Gardner has qualified as an expert in bloodstain pattern analysis and crime scene reconstruction in both state and federal courts.

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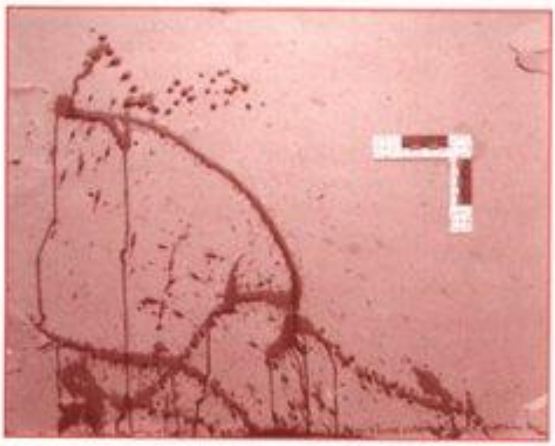
Forensic Science; Law Enforcement
Crime Scene Analysis; Criminal Investigation



Whether you're new to the field or have prior experience, this book demonstrates powerful analytical methods and techniques to help you investigate violent crimes. This in-depth reference and practical guide covers the analysis of bloodstain patterns found at violent crime scenes and outlines a logical, effective method for crime scene reconstruction. These techniques are presented in the context of how they are used to solve crimes.

The authors explain how to use bloodstain patterns to understand events that occurred at a crime scene, which includes a discussion of the role of logic in analysis. The book includes practical information on documenting and collecting bloodstain pattern evidence, presenting evidence in court, and contending with bloodborne pathogens. Numerous photographs graphically depict the concepts presented.

Features

- Includes a specific methodology for crime scene reconstruction
- Provides an in-depth discussion of how investigators can use bloodstain patterns to define events associated with a given crime scene
- Defines terms used in bloodstain analysis and includes many photographs to graphically depict the terms discussed
- Gives historic examples of the use of bloodstain pattern analysis in solving crimes

8159
ISBN 0-8493-8159-2
90000
9 780849 381591

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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 the historical basis and very likely the first usage 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 science or discipline, bloodstain pattern analysis seeks to define the facts surrounding some incident that is in question. The examination of the physical nature of

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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 of bloodstains, and their relationship to the surrounding scene are part of this aftermath. This information provides the investigator with a window to the past. 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.

The information we are likely to discover through an examination of the bloodstains includes:

- The direction a given droplet was traveling at the time of impact
- The angle of impact
- The probable distance from the target from which the droplet originated
- The nature of the force involved in the bloodshed and the direction from which that force was applied
- The nature of any object used in applying the force
- The approximate number of blows struck during an incident
- The relative position in the scene of the suspect, victim, or other related objects during the incident
- Sequencing of multiple events associated with an incident
- In some instances, which hand delivered the blows from a beating

The Relationship of Bloodstain Pattern Analysis to Crime Scene Reconstruction

Crime scene reconstruction demands that we evaluate all physical and testimonial 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."[3] Much as does the reporter, the investigator attempts to define the who, what, when, where, how, and why of a crime to assist in reconstructing the events. 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 boxtop. You really don't know what the picture is supposed to look like."[4] The investigator's box top is not available either. Despite

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this limitation, crime scene analysis and crime scene reconstruction attempt 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.

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, because they help associate items to our player and to 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 most 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* [italics added] of death." [5]

In the past two decades, bloodstain pattern analysis has reawakened to its role in documenting these circumstances. Bloodstain analysis brings to the investigation the ability to define those events that 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.

Thus bloodstain pattern analysis mirrors in many ways 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."[6] Bloodstain evidence in this role (acting as a scaffolding or part of the lattice) cannot stand apart from other evidence.[7] Reconstruction demands that we consider all evidence. Viewed from a holistic approach, all the evidence available should lead those who view it to a preferably 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. If this is done, another analyst cannot simply ignore this information. Granted, we may discover a secondary method of creation, but this simply adds a responsibility to discover which is the more likely event. If a stain is observable and reproducible, it

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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 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 must 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 as does 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. As we will constantly remind the reader, it is not enough that the analyst can reconstruct the bloodstain evidence. A reconstruction that fails to consider all known evidence is no reconstruction at all.

Second, analysts must understand their discipline. Bloodstain pattern analysis is far from being a static field. Our understanding changes every day due to research and experimentation. As we base bloodstain pattern analysis on the application of physical laws to blood, there are certain universal rules we can apply. These rules are as true today as they were when first observed. Understanding these universal applications, and then seeking those areas that require further study, should be the lifetime goal of every analyst.

Historical Perspective of Bloodstain Pattern Evidence

In seeking an understanding of bloodstain pattern analysis, it is important to look at its evolution. In his 1992 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."[8] This viewpoint, although inaccurate, is not uncommon. Out of ignorance, authors, judges, and investigators continue to proclaim the discipline as something "new."

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To those who spend time at scenes of violent crime, it seems unimaginable to ignore the presence of blood or not to ask some simple questions as to its relationship to the crime. Bloodstain pattern analysis, as we will see, is anything but new. It is only in the last several years that we have discovered some of the more important historical documents relating to bloodstain pattern analysis. The existence of these documents alters the somewhat biased view held by our investigative predecessors.

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 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.[9] Examples of this proof, although not quite *beyond a reasonable doubt* included "a criminal caught red handed."[10] The *Sachsenspeigel*, with its detailed illustrations, makes reference 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 with which its discovery is viewed. Shakespeare's various works, written between 1582 and 1616, like those of any author, 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?[11]

Although of little concern to modern bloodstain analysis, the *Sachsenspeigel* and Shakespeare's plays 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 Gellen-Kallela (*circa* 1897). It shows a young man with a bloodied sword and clothing as his mother points to numerous stains on his clothing (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

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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 National Art Archives, Helsinki, Finland.)

this story, the master of deduction concerns himself not only with discovering a reliable reagent test for blood, but also within the examination of "gouts and splashes of blood, which lay all around."[12] 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 several 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.

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In Germany and Austria, the universities at Kiel and Vienna appear to have been academic hotbeds of activity in bloodstain pattern analysis. Two significant authors of the time were Eduard Piotrowski and Ernst Ziemke, followed soon after by Dr. Balthazard of France.

The primary periodical in which many of the continental authors expressed themselves was the *Vierteljahresschrift für gerichtliche und offentliche Medizin* (*Quarter-Year Writings for Forensic Medicine*), published in Germany. Although much of the concern between 1850 and 1940 dealt with the identification of blood, scattered throughout these discussions are references to patterns observed at scenes.

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."[13] There is, however, no absolute translation and the terms sprinkle, spatter, splash, or spurt are all acceptable usage.[14] It becomes difficult, then, to always understand the specific context intended by any author. A 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.[15]

Although Lassaigne made it clear he believed "crushing" of dead flies created such stains, he implied that he 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 today as "fly specks." Unfortunately, the translation and overall description of 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 normal bloodstains.

In 1863, John and Theodric Beck wrote "Elements of Medical Jurisprudence." The article, as reviewed by Herbert MacDonell, discussed various cases in which bloodstain 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.[16]

In 1880, Dr. Henry Faulds published "On Skin-Furrows of the Hand," describing bloody fingerprints and their likely use to identify the criminal.[17]

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

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> 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…"[18]

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 of the University of Vienna in 1895.

Dr. Piotrowski's application of science 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, controlled and adjusted various variables to determine their specific effect on his experiments, and used live rabbits as victims! Although the latter issue would not sit well with many modern groups, Dr. Piotrowski recognized the dynamic nature of what he was studying.

Dr. Piotrowski considered this dynamic nature and used it as one of his variables. Calling the concept a "*complicertern morde*," he used multiple methods of attack against his study subjects (rabbits), thereby ensuring himself that he was considering all possibilities and their effects.[19]

In considering this *complicertern morde*, Dr. Piotrowski properly recognized the 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 he 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… [expiratory blood].[20]

Evident to 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.[21] 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."[22]

In 1901 Jürgen Thorwald, writing to describe the efforts of Professor A. Florence, stated:

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> [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.[23]

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 1904, Hans Gross wrote *Handbuch für Untersuchungsrichter als System der Kriminalistik,* in which he provided a detailed discussion of not only the evaluation of bloodstains, but also their collection and documentation.[24] Gross felt bloodstains were of critical importance in the investigation and thus devoted some 30 pages of the book to his considerations of blood and bloodstain patterns in the investigative process.

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 that 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.[25]

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 shapes of stains that might be encountered, Haberda wrote:

> 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…[26]

How similar to modern descriptions are Haberda's? *Round* and *bear paw* are still adjectives used to describe stains, whereas *elliptical* has replaced terms

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such as *club* or *bottle-like*. There can be little doubt Haberda was observing and classifying the very characteristics we still look for today.

Ernest Ziemke is another author of interest. His work is found in *Gerichtsärztliche und polizeiärtzliche Technik,* a book edited by Theodor Lochte in 1914. Chapter 7, entitled "Die Untersuchung von Blutspuren" (The Examination of Blood Tracks), was written by Dr. Ziemke and 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 [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.[27]

In discussing the search for blood, for both 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.[28]

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].[29]

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 (wave cast-off stains) in these instances would indicate 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

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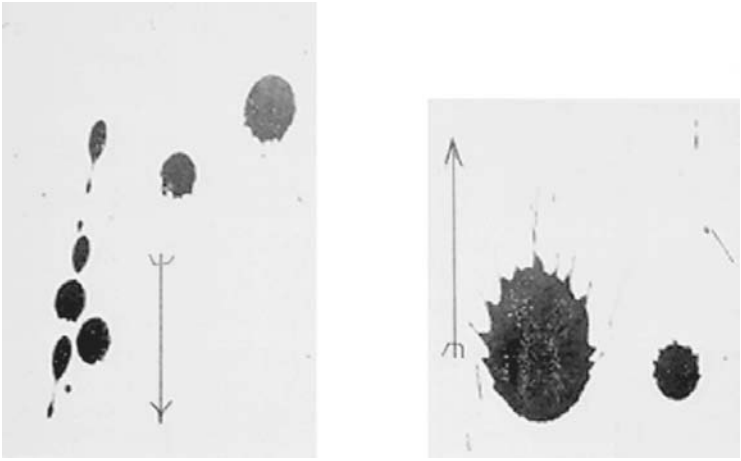

Figure 1.2 Illustrations from Dr. Ziemke's chapter (see Ref. 27) on bloodstain patterns that relate to defining directionality of the stain. The two figures (Ziemke's Figures 42 and 43) demonstrate a drip effect from walking and running. Ziemke added the arrows to show the directionality evident in the stains.

directionality. Figure 1.2 is an example of one of these illustrations. In closing his discussion of bloodstain patterns, he stated:

> 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.[30]

Dr. W. F. Hesselink, writing in 1931, considered various issues related to bloodstain analysis in his article "Blutspuren in der kriminalistischen Praxis." 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

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> 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.[31]

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.[32]

Hesselink sought to define not only the nature of the stains found, but also 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 this purpose 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.[33]

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.[34]

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. Rhodes did not comment himself on

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bloodstain patterns but gave specific mention to the efforts of Hans Gross in bloodstain pattern analysis.[35]

In their writings it is obvious that Hesselink and Rhodes clearly viewed blood from different perspectives. Rhodes understood what Gross was pursuing in the area of bloodstain patterns, but he felt the scientific individualization through the blood grouping systems of the time was of greater significance. Hesselink, on the other hand, felt the individualization and identification was secondary and that the patterns themselves were of greater significance. Today we recognize that both were correct. The individualization of blood stains 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, one of the most insightful papers relating to bloodstain pattern analysis was presented by Dr. Victor Balthazard, R. Piedelievre, Henri Desolille, and L. Derobert. Entitled "Etude des Gouttes 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.[36]

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. Like 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.[37]

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 his work. Analysts repeat his experiment in nearly every 40-hour bloodstain pattern analysis course taught today. In considering impact angle estimations, however, Professor Balthazard cautioned:

> 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.[38]

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:

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> 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.[39]

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.[40]

It is likely that world events in Europe prevented further significant development of Balthazard's research. Nevertheless, his group's efforts were not completely lost. 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 verschiedenen Unterlagagen die Fallohe und Richtung des gefallenen Tropfens Ermittelt Werden?" (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 from Balthazard's research. An interesting historical note: Dr. Gohringer completed his studies in December 1941 and was subsequently held as an internee by the German government for 7 months before he was released to Vienna. He later returned to the U.S., where he practiced medicine. In 1992, Dr. Gohringer spoke before the International Association of Bloodstain Pattern Analysts (IABPA) Training Conference in Colorado Springs, and shared some of his thoughts on the history of bloodstain pattern analysis.[41]

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. from 1935 to 1967. Kirk's book, *Crime Investigation*, published in 1953, included a chapter entitled "Blood: Physical Investigation," in which he discussed the application of bloodstain pattern analysis to criminal investigations.[42]

Another source for Kirk's beliefs on the subject is his affidavit filed in the Court of Common Pleas, Criminal Branch, in the case of the *Ohio v. Samuel H. Sheppard*.[43] This document provides immense insight to 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

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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.*

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

1. Bloodstains resulting directly from extravasation — 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

As with previous authors, Dr. Radziki cautioned that a critical consideration were the characteristics of the target surface, because blood stains created under similar circumstances but falling to different targets might well result in dissimilar stains. Another interesting point made by Dr. Radziki included his assertion 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.[4]

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 throughout 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 on your individual perspective. What cannot be denied is that Herbert MacDonell brought about a distinct reawakening of this discipline.

* We must make one point when considering this document. Whereas Dr. Kirk's knowledge and consideration of bloodstain analysis are unquestionable, we feel his reconstruction in the Sam Sheppard case is difficult to defend. He managed to interweave extremely subjective information into his opinion of what was or was not a fact.

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In 1970, after conducting extensive research, MacDonell and Lorraine Bialousz coauthored *Flight Characteristics and Stain Patterns of Human Blood*. Because 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*.[45] 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 Sciences* 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 often referred to as "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 an angle greater than that which occurred. Their findings are extremely important in our efforts to understand dynamic scenes of crime.[46]

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 for Identification (IAI) accepted bloodstain pattern analysis as a tentative 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 the second edition of *Interpretation of Bloodstain Evidence at Crime Scenes* with CRC Press, significantly adding to its value. Prior omissions were corrected and the text remains a valuable reference.

James followed this work *with Scientific and Legal Applications of Bloodstain Pattern Interpretation*. James put together an impressive group of contributors, including Alfred Carter, Ph.D., William Fischer, Carol Henderson, Paul Erwin Kish, Maria Saccoccio, and T. Pualette Sutton. The text was

* In support of this role, each year the IABPA hosts training seminars dealing with bloodstain pattern analysis and other related forensic disciplines.

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directed toward trial counsel in an effort to help lawyers better understand how to apply bloodstain pattern analysis in criminal trials.

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. 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. As analysts, our purpose 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.[47]

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Crime Scene Analysis and Reconstruction

2

Before proceeding to the specifics of bloodstain pattern analysis, it seems appropriate to consider crime scene analysis and reconstruction in their own right. Bloodstain pattern analysis is so closely related to the tenets of crime reconstruction that it is difficult to separate them as distinct processes. The reason for this difficulty is that bloodstain pattern analysis seeks to answer the question "what happened." Any attempt at bloodstain pattern analysis is in effect a partial crime scene reconstruction. Often, bloodstain pattern analysis will provide a significant source of the information used in the crime scene reconstruction. Therefore, the bloodstain pattern analyst must understand and apply acceptable scene reconstruction methods.

The problem in the past has been that although discussions on crime scene analysis abound, few defined methodologies existed in the written literature to provide the analyst with a reference or starting point from which to understand how to conduct a crime scene analysis.

The Association of Crime Scene Reconstruction (ACSR) 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 the term *event analysis* as well. All three terms relate to the same idea.

The concepts behind crime scene reconstruction are not new. There is a significant history in forensics relating to reconstructing criminal events using physical evidence. Although the methods have not been well documented, clearly investigators have and do apply formal methodologies to this task.

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Hans Gross was one of the first forensic authors to elaborate on crime scene reconstruction. Gross' book, *Handbuch für Untersuchnungsrichter* (*Handbook for the Investigating Judge*) was perhaps one of the first well-known criminal investigative references. Gross discussed his thoughts and ideas on the reconstruction process, without actually referring to it as reconstruction. Nevertheless, he felt observation of the scene to be critical and stated "criminal investigation consists of … the application of all useful technological and scientific information to solve and support allegations in the courtroom."[2]

The Wizard of Berkley, Edward O. Heinrich, was well known for his skill in forensic detection. Active throughout the 1920s–1940s in the San Francisco Bay area, Heinrich described his methods for reconstruction as follows: "My procedure is to reconstruct the crime by 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."[3]

Charles O'Hara published the first edition of his book *Fundamentals of Criminal Investigation* in 1956. This text was a standard in academic criminal justice programs for many years. In Chapter 4, O'Hara discussed reconstructing crimes, indicating the reconstruction was accomplished both through 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.[4]

In 1984, Jerry Findley and Craig Hopkins, in a paper discussing their reconstruction techniques, wrote, "In essence, reconstruction is the sum total of the investigation demonstrated in its tangible form."[5]

James W. Osterburg wrote his text, *Criminal Investigation: A Method of Reconstructing the Past,* in 1992. In it, he 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 defined methodology for reconstructing crime was presented by Chisum and Rynearson in 1989 as part of their work *Evidence*

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and Crime Scene Reconstruction. Their ideas and concepts were a significant step forward, certain aspects of which are discussed in greater detail later in this chapter.

Dr. Henry Lee wrote his text *Crime Scene Investigation* in 1994. Lee included a chapter on reconstruction, in which he commented on the importance of using all forensic disciplines as input to any reconstruction. Lacking in his work was a discussion of his methodology. Lee offered only that the scientific method was the underlying process to a reconstruction, but failed to provide practical steps as to how this is achieved.[6]

Chisum subsequently contributed a chapter to Brent Turvey's book, *Criminal Profiling,* entitled "An Introduction to Crime Scene Reconstruction." He made it clear that reconstruction was a necessary part of the profiling process, but unfortunately, did not take the opportunity to outline in depth or expound on his previously published beliefs on the process itself.

It was the development of criminal profiling methods in the 1980s that served as somewhat of a catalyst for bringing crime scene reconstruction into the forefront of investigative literature. This association, however, created significant misunderstanding of what crime scene analysis really entails.

Correlating Crime Scene Analysis to Behavioral Analysis

To consider crime scene analysis we must first provide our own definition, specifically contrasting it with the criminal profiling work started by the Federal Bureau of Investigation's Behavioral Sciences Unit (BSU).* This distinction is important because many people closely associate criminal profiling with the term "crime scene analysis," so much so that they are often considered synonymous.

Criminal profiling provides an outstanding service in serial and violent crimes, which often assists 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 suspect as an individual. The information derived from the process can be valuable. It is also a subjective process, and a good profiler will explain to the prospective client that these methods are not without fault. 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. This is a

* The Behavioral Sciences Unit was recently incorporated into the FBI's National Center for the Analysis of Violent Crime (NCAVC).

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circumstance that fails to fit the statistical data used to assist in developing such profiles.

Criminal profiling is, however, 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 of time, but as Geberth noted, psychological profiles are nothing new to criminal investigations.[7] 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 to develop an early form of profiling. Heinrich's methods included consideration of the scene as well as victimology.[8]

Another notable exception to the post-arrest psychiatry approach to profiling was the work of Dr. James A. Brussel during the 1940s and 1950s. Dr. Brussel used his psychiatric training 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, stated simply:

> "Look for a heavy man. Middle age. Foreign born. Roman Catholic. Single. Lives with a brother or sister." [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.[9]

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 efforts 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."[10]

Modern criminal profiling generally consists of three stages:

- Collecting profiling inputs: the crime scene, victimology, forensic information, police reports, background information, and photos
- Creating decision process models: defining the homicide style, primary intent, victim risk, offender risk, location, and escalation
- Conducting a crime assessment: reconstruction of the crime, crime classification, staging issues, motivation, and crime scene dynamics[11]

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In his description of the assessment phase, Ressler 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.[12]

Chisum commented as well on the necessity of integrating crime scene reconstruction techniques into the criminal profile process, stating:

> Criminal profilers have realized the need to reconstruct the crime. To explain the behavior of the criminal they need to know what was done at the scene. The study of the crime scene holds many answers to the motives of the suspect, but only if the crime is understood.[13]

It is apparent, then, 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 what can only be described as a subjective process. As Turvey reported, "forensic analysis is of paramount importance because it helps to preserve the criminal profilers' objectivity by protecting them from investigative assumptions."[14] An integral and unmistakable part of the third step of criminal profiling, crime assessment, is reconstructing the crime in a particular manner that we will describe in this chapter.

Our discussion of crime scene analysis will concentrate 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. It is our position that having defined the reconstruction in this fashion, one may always expand it to consider the more subjective information available and any hypothesis based on such information.

Crime scene analysis, then, is the process of defining events supported directly by physical evidence. The first step in accomplishing this is the proper recognition and collection of such evidence, which is followed by a formal analysis.

Reconstruction is the end purpose of analysis; it requires not only the consideration of the events identified, but, whenever possible, the sequence of those events. Reconstruction in this sense does not demand that the analyst identify a motive or intent behind some action. As we have stated, understanding human behavior during a crime is an issue fraught with subjectivity.

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Attempts to assign motive or intent to the specific events within the crime add immeasurably to the problem.[15] We do not offer exclusion of this concern as an alternative; rather, we simply think it best to conduct an objective evaluation, delaying our consideration of motive until the latter stages of the investigative process. Objective, clear information must be the basis and foundation of any initial reconstruction or analysis.

In this chapter, we will first consider a conceptual model of analysis, looking at the function of collection, evaluation, assessment, and integration of evidence from the scene examination. Later, we will offer a specific methodology based on the scientific method, with which the analyst breaks down each incident into events, event segments, and their supporting evidence, considering each part in and of itself, then together as a whole. Lastly, we will consider the function of logic and its effect on decisions the analyst makes.

Limitations in the Reconstruction of Crime

Before progressing further we must accept the limitations of the reconstruction task. Much as in the archaeologist's dilemma, we seek to revisit a past event and define it accurately for the court. The problem is that no true standard will ever exist to which we can compare our conclusions.

Just as limiting to the reconstruction is the fact that no matter how smoothly the investigation proceeds, in the end what we know is often far less than what we don't know. In part, this is due to limitations in 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 encompassed the crime.

The Rodney King incident in Los Angeles in 1989 is perhaps the best example of how truly limiting the reconstruction process can be. 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 valid and convincing evidence claiming completely opposite positions.[16] Even with the tape, deciding whether this action transpired was anything but simple for the jury.

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.

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In viewing our scene to define these events, 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 event or action. For example, a contact gunshot wound indicates the weapon was in contact with the victim; thus, whoever operated the weapon also must have been in an appropriate proximity. A latent fingerprint tells us clearly that the depositor of the fingerprint had contact with the item on which it was found. This type of evidence speaks clearly and concisely to everyone.

C*ircumstantial evidence* provides direction but lacks distinct focus. 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 still important, but it demands that we carefully consider any conclusions we draw from it.

In defining *peripheral evidence*, let us 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. Oftentimes this type of evidence creates major distractions, not only during the investigation but also in the subsequent judicial proceeding. Because we are not clear as to how it relates to the scene, wild and insupportable claims are often made regarding that relationship.

In pursuing a reconstruction we seek to define physical events that we were not present to observe. Therefore, we must always remember that:

- These events are dynamic. In other words, any number of similar events may produce the result we observe. These similar events, however, may deviate in slight but important ways.
- The nature of the evidence to support our decisions on these events, even in the best of circumstances, will probably provide only a glimpse of this past.
- Rarely, if ever, will we have a standard to which we can objectively compare our conclusion.

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

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picture is simply the most probable definition available based on experience and the evidence available to us. For this reason we should never attempt to define too narrowly the events surrounding an incident. Our responsibility is to make this an objective picture, inferring as little as possible.

Application of the Scientific Method in the Reconstruction Process

Given the limitations associated with the reconstruction process, it might well be argued that crime scene analysis is anything but "scientific," and in fact such claims are often forthcoming in court. Often, in attacking an analysis, opposing experts and lawyers imply that only the "scientist" can apply the scientific method; mere mortals such as analysts, investigators, and police officers are incapable of understanding or applying its mysterious tenets. In such arguments, one can be sure that the counselor will use great emphasis and intonation each and every time he or she uses the word "science." More often than not, these individuals have no clue as to what the scientific method is or exactly what it entails. Nevertheless, by furthering this common myth, that it is something mysterious, magical, and beyond the average human's understanding, they hope to prevent the presentation of critical information. So what is the scientific method and how does it relate to the crime scene analysis process? Can we really hope to understand and apply it to the investigative process?

First and foremost, the scientific method is not some mysterious, complex, nor magical thing. It is, in its simplicity, a defined process used to resolve complex problems. The 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 the scientific method creates an ever-expanding and self-correcting body of knowledge related to some specific issue.

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

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

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> 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 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.[17]

Thomas Huxley, a 19th-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.[18]

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 than are the police to handle a criminal investigation from start to finish. Trained observation, discrimination, and a sense of the value of evidence are necessary skills that police experience provides.[19]

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

> [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.[20]

Pirsig's interesting association is quite accurate. Humans tend to resolve problems using an odd mixture of empirical observation combined with rationalism in order to make sense of complex or abstract issues. This mixture is itself the very nature of the scientific method, which seeks to blend empirical

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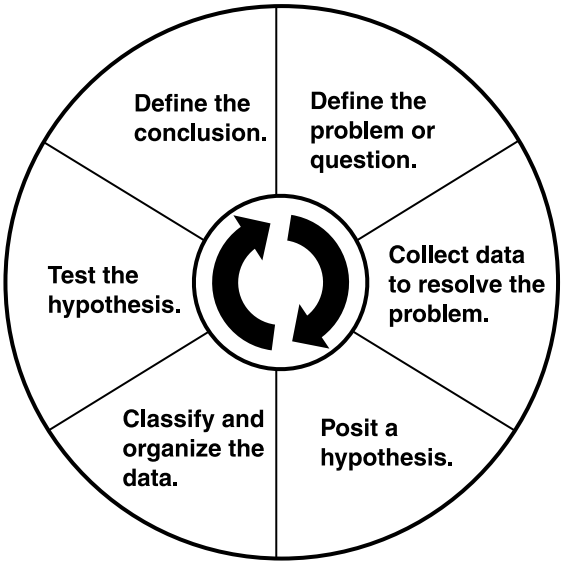

Scientific method starts with a question, the answer to which usually begs another question. As a result, scientific method is often referred to as circular process.

Figure 2.1 The 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 the scientific method is an ever-expanding and self-correcting body of knowledge.

knowledge (that gained through observation and deduction) with rationalism (that gained through application of reasoning and inductive thought). However, the scientific method is precise and provides structure to the process. That structure is achieved through six steps (Figure 2.1).

The first step in the scientific method is to identify the problem to be resolved. 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 down a larger problem into smaller subproblems. When we introduce the event analysis process later in this chapter, the importance of dealing with discrete, small problems will become quite evident.

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 blood stain, where in the established taxonomy or categories of bloodstain pattern analysis does it fit?

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- Given the established category, what mechanisms were present in the scene to create the stain?
- Is one mechanism more probable than another, and if so, why?

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

The second step 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 typical laymen's icon of the 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 police tend to be less skilled than our "scientist" counterparts; therefore, great care should be used to design experiments properly. In Chapter 10 we will discuss some pitfalls associated with designing and conducting such experimentation.

The third step of the 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. For each hypothesis, predictions are identified. These predictions will be the basis for testing the hypothesis against the data collected.

The fourth step is to classify and organize the collected data for interpretation. As previously mentioned, having the data and understanding the data are two entirely different things. We must examine the interrelationships of the data in an effort to find our answers.

The next step is to test the hypothesis by comparing our expectations 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 that this mechanism was available and present at the scene. Furthermore, we may be able to create a similar mechanism and employ it to create a similar type of stain. It is important to recognize that, in terms of finding answers to problems, the scientific method is far more effective for disproving a given hypothesis than for proving a single hypothesis. Often referred to as *premise negation*, the scientific method will allow us to state with some level of authority that certain things could *not* have occurred, but it won't always allow us to identify exactly what occurred.

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After testing a given hypothesis, the analyst is left with one of two possibilities. Either the hypothesis is supported by the data, indicating it is possible, or the hypothesis is rejected and excluded as a possibility. If rejected, the hypothesis must be altered or an alternative hypothesis considered. Remember always that in the scientific method, it is the data that define the conclusion and not the conclusion that defines the data. This important nuance is often lost on professionals, scientific background or not, and manifests itself in individuals rationalizing why certain items of evidence or data are unimportant or "don't matter."

The final step in the scientific method is to draw a conclusion from the information examined. What one concludes depends on 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, perhaps, is one of the more important aspects of applying the scientific method, that is, in recognizing what we don't 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 seemed to have slightly the advantage of him."[21] Analysts must always remain cognizant of what they do not know.

It is in the conclusion that the greatest misunderstanding of science and the scientific method lies. Truly 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 better understand this issue, 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 Galleo has been to expose nature's general covering laws."[22] Hawkins also commented on this, stating, "The eventual goal of science is to provide a single theory that describes the whole universe."[23] Hawkins went on to explain, however, that the two basic theories by which science understands our universe — general relativity and special relativity — 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 both theories as the best explanation possible at the moment, while seeking a combined theory that will incorporate them both 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 (similar to our concept of direct evidence), which lie closest to truth. Primary data are "the most illuminating, the most truth manifesting," whereas secondary data (our concept of circumstantial and peripheral evidence), although helpful, lie further from the realm of truth. Cautioning the research student to be wise enough to know that what one makes from the data is truly only a glimpse of the ultimate truth, Leedy stated:

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> 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.[24]

The scientific method provides us with an understanding, a recognition of what the data represent. At times the data may be very precise, providing clear and specific information in some area of a reconstruction, but more often the data will allow us only a glimpse at what happened. Just as scientists now accept that the two theories of relativity are the best understanding of our world given our current knowledge, we must accept that a conclusion derived from the scientific method brings us only to the most probable.

But does applying the 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 phenomenon and works backwards 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 backwards. Nordby 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.[25]

We don't presume to state that investigations and the reconstruction process are "science," but they can and should follow the scientific method. Done properly, both mirror the role of science, by logically deriving explanations for specific events.

A Conceptual Model for Analysis

The process of analysis involves four stages when considering any piece of information. (In the following section information and evidence may be considered synonymous.) These stages are

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- Collection
- Evaluation
- Assessment
- Integration

The first is perhaps the investigative benchmark, for without collection there is nothing to analyze. The latter three serve specific functions in deciding whether some piece of information has value to the investigation.

In discussing analysis, we need to introduce three terms that relate to a reconstruction process called *event analysis*. We will discuss the terms in greater detail later in the chapter, but a definition of each is helpful at this point.

Incident: all of the actions related to the crime or situation
Events: each event is some part of the crime (a macro view); they can be defined by either specific actions (event segments) or specific items of evidence
Event segments: distinct moments of the crime defined by some specific action and supported by physical evidence (a micro view)

Collection and the Generalist Attitude

Obviously, evidence that is neither recognized nor collected has no value to the investigative process. If responsible for the initial scene processing, the analyst must know what evidence to look for and what it can tell him or her. Knowledge and experience in all areas of forensics and criminalistics are essential for any analyst. A "generalist" attitude must prevail in the analyst's mind: that is, to become familiar with and remain current on forensic advancements. Because any area of forensics may affect the consideration of evidence found at a given crime scene, the analyst must be able to interrelate the various disciplines. This ability combined with a "scene sense" is an absolute prerequisite to becoming a crime scene analyst.

Evaluation

The first stage in a formal reconstruction is evaluation. In the process of evaluation the analyst considers two subissues, reliability and credibility of the evidence or information. Reliability affects crime scene analysis in a very minimal sense because it considers the source of the item or information. In most instances, the source for any given piece of evidence is the scene itself. If we find the evidence within the scene, we accept its trustworthiness unless issues of staging or contamination are evident or possible. Learning to be cognizant of such issues is an integral part of the investigator's scene sense.

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In view of this concern, we need to ask several questions of those who respond to the scene (e.g., officers, firemen, EMTs). For example:

- What did you do there? Where did you park, what equipment did you carry in, or what route did you enter through?
- What did you move in the scene? What items did you touch, or what doors, windows, or lights did you change from their original configuration?

Failure to ask these questions is a failure to properly consider the reliability issue.

Staging of the scene — situations in which an individual creates false evidence to mislead us — presents an odd contrast. Staging certainly impacts on issues of reliability for reading the scene as it was left for us to view. Yet, staging is an integral part of the scene and represents reliable, distinct evidence in and of itself. Our concern, then, is to recognize the investigative "red flags" that point to staging.[26] Once the issue of staging is on the table we must then attempt to differentiate the evidence that is accurate as a reflection of the true event from that which the subject designed to misguide us.*

Another reliability issue may be the evaluation of the condition of evidence observed but not recorded for subsequent viewing. In such instances we must consider the ability of any source (e.g., witnesses, officers) to effectively observe, register, and then report the information. It would be preferable to see such evidence firsthand, but if it was moved, destroyed, or otherwise damaged our source's observation of such evidence may be all that is available. If we reasonably assume our sources are reliable, we cannot dismiss their observations, nor should we.

After considering source reliability, the next subissue in evaluation is to consider the credibility of the information or evidence in question. Credibility considers issues such as:

- Is the action or evidence in its current condition possible?
- Is there corroboration to the evidence?
- In considering the other evidence available, does this item present any specific contradictions?
- If such contradictions exist, can we reconcile them, or is one inherently less accurate than another?

* To a great extent we would agree with Professor Haberda regarding the ability to read a scene: the analyst learns this ability not from books or classroom lecture; it is learned singularly through experience.[27]

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Credibility, as evident from the preceding questions, has a direct relationship to establishing issues of staging or inadvertent contamination. This step assists in considering if a particular piece of evidence found at a given scene is related to the event in question. In effect, we apply a "tree vs. forest" approach, evaluating the specific item first in view of itself, then contrasting it against other evidence known to us.

Having considered reliability and credibility, at the end of the evaluation phase we should feel reasonably sure which information is trustworthy and which is less reliable. It is important to note that although we may place some piece of evidence in a less-than-admirable light following evaluation, we should not discard it entirely.

Assessment

Following the evaluation phase, the analyst must assess the information. Assessment considers the information in light of what it does or does not prove. We start asking simple questions regarding the evidence, and by answering them we establish the specific events or event segments that will eventually make up our overall reconstruction of the crime.

Rynearson and Chisum, in discussing crime scene analysis, considered all evidence in terms of time and surroundings.[28] Although this approach to assessment is functional, we prefer several modifications.

The analysis will eventually bring us to a point of defined actions, or what we call event segments. Each item of evidence speaks to some event segment where it was created or used. In reconstructing the incident, we must consider each event segment and the information that supports it with three objectives or questions in mind:

- What is the basic nature of the segment and evidence?
- What relational aspects to other segments and evidence exist?
- What time and sequencing aspects are present?

In considering the basic nature, we seek to describe the event segment or evidence in its simplest form. In describing evidence we start simply with: What is it? In answering this question for an event segment, our answer is likely to consider: What was the nature of the occurrence? We also look at the function or purpose the evidence or action served. This often leads to the question: Was it used as intended, or did it serve an alternative function? (See Figure 2.2.)

Our next consideration is to see what relation the event segment or evidence has to other events, event segments, and evidence found in the scene. What interrelationships exist between the various articles of evidence or the scene as a whole? (See Figure 2.3.)

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Basic Nature Issues

At a rape/homicide scene we discover two items of specific concern:
- a wire which is fashioned in a loop and left in place in the victim's mouth.
- a small bloody mark on the victim's thigh.

What is it?

We determine the wire is heavy gauge electrical wiring, similar to that used for AC wiring.

The blood spot is a swipe mark. It holds limited characteristics of a fingermark.

What function did it serve?

The looping device is not the mechanism of death. It appears to have served as some mechanism of control. What we are not sure of, is if this was a true mechanism of control or a prop related to the subject's fantasy.

There is no blood source evident for the swipe. It doesn't appear to be a ritualistic marking and gives the appearance of being an accidental contact.

Figure 2.2 In answering basic nature issues, we ask simple questions regarding the items of evidence we find. What is it? What function did it serve? We keep our focus clearly on the item itself, without drawing broad conclusions based on other evidence.

Such considerations help us link the evidence in some fashion to the scene, victim, subject, or other involved parties. Here the classic forensic linkage triangle is important[29] (Figure 2.4). Our function is to relate the three primary players (scene, victim, and subject) to one another by considering how each of the actions may tie any of the three together. With regard to the event segments, a specific concern is to determine which segments appear related or result from a common event.

Other obvious relational questions emerge: Is this item foreign to the scene? If so, why and how did it come to be here? This further demands a reevaluation of the basic nature issues. In the Figure 2.3 example, the presence of the wire in the scene seems to indicate it is foreign. This may eventually point to some link (e.g., an occupational link) between the wire and the subject.

Throughout the evaluation and assessment the analyst must not only consider what is found but also ask what is missing from the scene, constantly watching for negative evidence issues and documenting the presence of such a condition. Negative evidence may play a distinct role in evaluating a situation where there are several possible events. It serves as an auditing method, which we will discuss later in the chapter.

Having dealt with the basic nature and the relational aspects of the evidence, this information will lead the analysts to a point where they can

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Relational Aspects

Relationship to the Scene

We find no similar wire anywhere in the scene. It appears to be foreign. We do find small traces of similar insulation on the floor in the scene.

There is no other blood present in the scene.

Relationship to Other Evidence

Examination determines the wire and insulation exhibit similar toolmarks.

The blood is inconsistent with the victim. But small blood traces under the victim's fingernails are found to be of a similar type.

There are no usable latent characteristics in the swipe, other than to verify the likely source as a finger.

The tool, wire source, a minor injury, and the subject's blood type represent future means of linking our subject. Certainly the wire itself may indicate an occupational link to our subject.

Figure 2.3 Considering our evidence against all other evidence, we attempt to establish links between the various items we find. This also provides a future focus for evidence we may need to seek out.

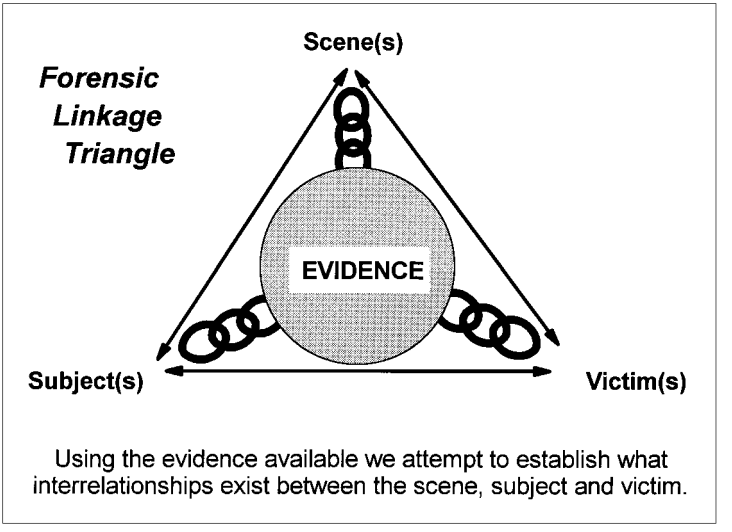

Figure 2.4 The crime scene analyst uses the concept of the linkage triangle in considering every item of evidence found. In what fashion will it establish specific links among the victim, scene, and subject?

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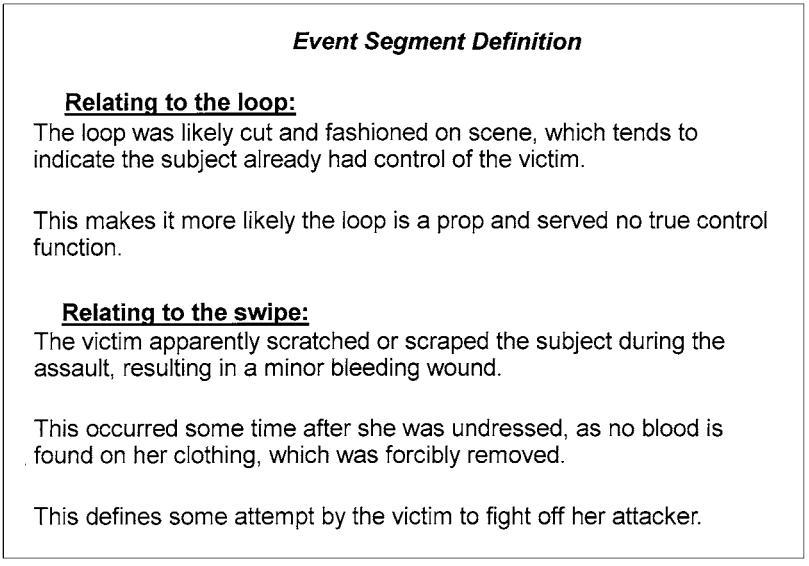

Figure 2.5 All of our prior considerations eventually lead us to a point where we can define specific actions or aspects of the incident, known as the event segments.

define specific event segments (Figure 2.5). The next concern is that of time and sequencing effects. We must now use the evidence to establish or define:

- Specific information related to the actual or relative time of the crime
- The sequence of events or event segments associated with the crime

Sequencing information is extremely important because it assists the analyst in ordering the event segments during the integration stage of the analysis. Time and sequencing aspects, however, are distinct. For example, rigor follows a basic timeline in its onset and departure from the corpse. Identifying the stage of rigor present at some point often gives indications of when the individual was killed. In other words, it places the time of the crime. Granted, we cannot take the rigor timeline as absolute, but it does point to the passage of time since the crime. A broken watch may point to the time of an altercation; this of course assumes we have sufficient reason to believe it broke during the incident in question. We often seek to identify interruptions of daily schedules to give us information relevant to when the crime may have occurred. Each of these types of evidence or events points to the actual time of the incident. They serve only a limited purpose in sequencing the events that encompass the incident itself.

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Sequencing, on the other hand, helps define where the various events and event segments belong in the overall picture. For example, distinguishing a stain as a wipe indicates the deposit of the blood first, followed by its disturbance. The analyst must constantly seek out information that will assist in the sequencing process, for this is the very heart of the reconstruction.

In considering time, Rynearson and Chisum identified three effects related to time that are of specific concern:

- Predictable effects
- Unpredictable effects
- Transitory effects[30]

We look at things such as the progression of rigor and livor as predictable effects. Perhaps a good example of a predictable effect in bloodstain pattern analysis is the time required for skeletonization to begin. As Pex and Hurley noted, this time is very short in individual spatter or stains, beginning within 30 to 60 s after the stain deposit.[31] If we find disturbances within such stains without evidence of skeletonization, this places the action of disturbance very close to the time of deposit of the stain.

Rynearson and Chisum considered unpredictable effects to be those effects that we cannot control. Such effects tend to destroy the value of evidence at the scene. Inadvertent contamination, destruction, and altering of evidence are examples. Unpredictable effects most often impact on how the analyst views the evidence and incorporates it into the analysis.

Transitory effects include effects that are fleeting. If unrecognized, they may well be lost forever. They are often referred to as fragile evidence, and a failure to recognize and record their condition could be disastrous. Reliability issues become important in dealing with such concerns. We cannot ignore reports of evidence of this nature, but we must be confident of the source's ability to have effectively observed and remembered this evidence.

During the assessment phase the investigators will generally establish a set of questions that are of immediate issue. They then seek to answer these questions using the assessment process described. This is not to say the investigator is looking for "his or her answers" and nothing else, but without some basic questions to consider, assessment serves no logical function nor, for that matter, would the investigation. Examples of initial assessment questions might be:

- How did the subject enter the dwelling?
- What instrument was used in the assault?

Often, after viewing the scene and considering the analysis, the investigators may find they are asking the wrong questions and have an inappropriate

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focus. To correct this the investigators must be willing to reformulate their questions, considering any new knowledge. The only limiting factor in assessment is the analyst's willingness to clear the slate and start the process again. Much as Geberth commented that "flexibility and common sense" are key ingredients to successful homicide investigation, these elements are also critical to any attempt in crime scene assessment.[32]

What is unfortunate is that often we find ourselves aligned to ideas that too narrowly define the questions being asked. The analyst must be willing to consider any possibility. As Dr. Jon Nordby wrote, "Detectives are not ordinarily in the habit of reasoning to generate novel hypotheses, instead they habitually reason to select the best model from among a given set of fixed alternatives."[33] In effect, we attempt to fit our observations of the evidence into narrowly defined conclusions. For example, we may attempt to define a death as murder, without considering suicide, autoerotic, or accidental causes.

Failing to find corroboration to the analyst's initial set of questions invariably leads the investigation in some new direction. If we lack evidence that a "subject" entered our death scene, then our focus should shift to questions of whether evidence is present to support suicide or accidental death. Remember, the questions asked in assessment are simply a guide: the analyst must be ready to readjust the focus at any time.

Another consideration in assessing evidence is giving credence to both the positive and negative aspects of the evidence. The analyst must ask: How does this evidence support alternative hypotheses? Inexperienced investigators often make the mistake of assuming evidence singularly proves or disproves some issue. This might occasionally be true, but it is more often the case that an item of evidence may support several points of view.

We must also evaluate the relevance of the information or evidence, considering all questions at issue. Simply accepting the evidence for what it apparently proves or disproves on its face may lead to overlooking valuable links. This is particularly true if one considers scenes of crime from the point of view that nothing "just happens." Every event has some series of actions that lead up to it.

These background actions may have no specific relevance to the crime, nor will they in every instance be of concern to the investigation. In some instances, however, the relevance of these actions may be to determine which of two possible event segments is the more likely occurrence. This process is referred to as *auditing*. It represents a means by which to cross-check the evidence just as an auditor cross-checks financial records. On their face, a company's financial records may look correct, but the auditor examines each and every transaction, tallying debits and credits in order to locate mistakes or inaccuracies lost in these transactions. In the same fashion, the analyst

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examines the minute detail in the evidence in order to recognize discrepancies in theories or hypotheses, or to determine which is the more probable of several competing hypotheses. Auditing can often assist the investigator in establishing the staging of a scene by identifying situations in which evidence simply "appears" within the scene.

To understand this process, imagine a situation in which we are faced with two possible sequences, both of which might explain evidence discovered at the scene. The evidence related to what happened supports both possible events equally. We are left, then, to objectively choose which of these events is the more probable.

If we look beyond the immediate issues and find background evidence supporting the occurrence of Event A but no such evidence to support Event B, from the reconstruction perspective Event A is the more probable event. Later in the chapter we will give the reader a more detailed example of this auditing process.

By the end of the assessment phase the analysis should have distinct form. The questions asked by the investigator have been revised and a primary focus found. Much like a half-finished jigsaw puzzle, certain portions of the reconstruction are clear in form, content, and context. We have defined events and event segment sequences, which are based on the evidence discovered. From the evaluation and assessment, we know how reliable the information is and we have a clear view of what each proves in and of itself. Remaining are the sections where we think we see patterns in the event segments or have some hazy focus of which we are not yet confident. Of course, we also have those pieces that fit in no fashion to the content and context as we understand it.

Integration

Our final task in analysis is to integrate the information and evidence with all other known information and seek "to form a logical picture."[34] We have reached the ultimate goal of the analysis: How do these pieces fit together and in what fashion did the events unfold? It is here that our analysis begins the transition to a true reconstruction. The sequencing information developed during the assessment process is the primary foundation of integration. We combine it, of course, with a simple, common-sense approach.

In accomplishing integration, we must consider that crimes do not occur instantaneously. From our facts and evidence we will establish "time snapshots or windows."[35] Each window has a set of facts that ultimately support our belief for that snapshot's occurrence (Figure 2.6). The increments for such windows may begin as large chunks of time, in that we attempt to define gross aspects of our reconstruction. As individual pieces of information begin to fit into the overall picture, we enhance our ability to break up the time

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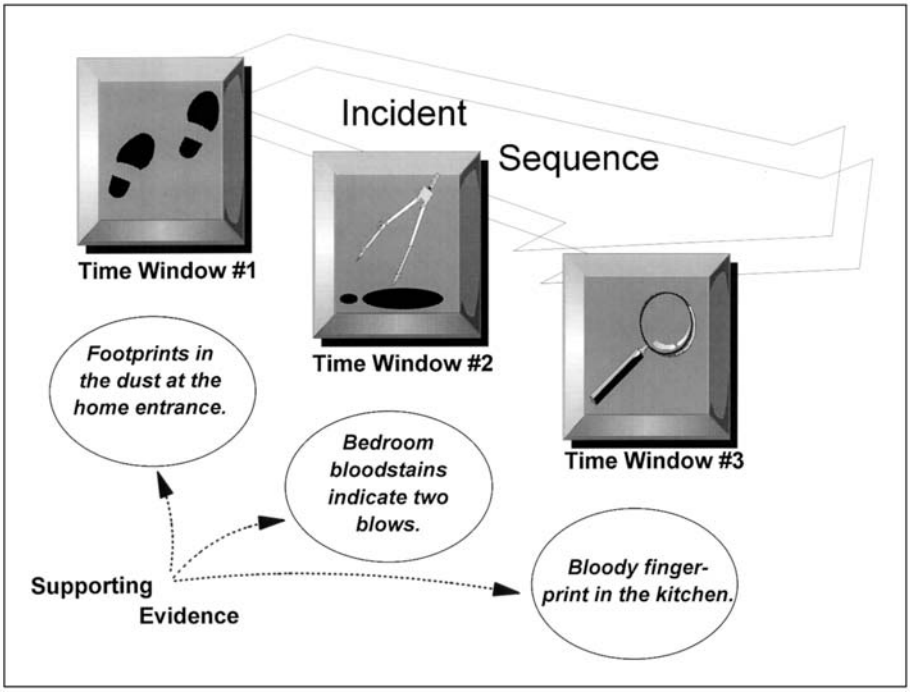

Figure 2.6 Crime does not occur instantaneously. Thus we attempt to establish "time windows" or "snapshots" of the actions that encompass the incident. We then sequence these snapshots using the available evidence.

increments. This process is a simple extension of the long-honored use of "timelines," which investigators apply in most serious crime investigations.

As the reconstruction develops, our time increments for one section may be small and precise in defining the events that occurred, yet for another period the increment may remain large. The distinction between the two is our ability to accurately define the detail present in the evidence. Obviously, the smaller the increments the more detailed the analysis, and the more likely our reconstruction will be an accurate representation of the incident.

In terms of serving the reconstruction process itself, these snapshots, when considered sequentially, may help us identify some part of a missing picture. If we have a factual beginning and end to some event of the reconstruction, the "logical" missing piece may identify in what direction we need to focus investigative efforts to prove or disprove our beliefs about this missing piece.

One final caution is appropriate when considering the integration phase. What has been a logical development of the crime scene analysis is at severe risk of becoming garbage in this latter stage. When asked to pull the pieces together, we tend to go overboard. Subjective considerations creep into what

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should be a relatively objective process. In trying to build a neat and tidy package, we begin to make assumptions about what the participants thought, felt, or even said. By doing so we also inappropriately fill in gaps in our knowledge with information that has no supporting basis.

Our goal in integration should be to remain unattached to issues of intent or motive unless they are clearly proven by concise knowledge. We should concentrate our efforts on piecing together the event segments that we can factually prove as having been accomplished during the crime. Thus, when viewing the crime as a series of actions it may be easier to subsequently define motives, or perhaps recognize anomalies.

As an example of this issue, consider what the BSU defines as the "signature." We differentiate signatures from the *modus operandi* (MO) in that most often the MO is a set of actions necessary for the accomplishment of the crime. As criminals learn and gain experience, MOs often change to exhibit this criminal maturity. A signature is some action taken by the criminal which, considering the crime, is quite unnecessary. Signatures tend not to change with time and often have significance in a very personal manner to the criminal.[36] We may recognize the action as a signature, but its significance to the subject may totally elude us.

If we fail to consider the crime as a series of subset actions (event segments), the lack of necessity for the signature action and thus the identification of that action as a "signature" might go unnoticed. On the other hand, should we become too focused on the signature by seeking the action's significance to the criminal, we may lose sight of other important evidence while chasing what may be a minor point in terms of reconstructing the event. Even worse, we may incorrectly assume its significance and end up tainting the overall reconstruction.

Integration takes each piece of the puzzle and attempts to place them together to form a whole picture. Just as in the jigsaw puzzle, the analyst cannot try to force information into what looks like the "right" place. If some portion of the evidence contradicts its usage, we may need to set aside that information until we can establish its rightful place. We must also recognize that because our puzzle's box top is not available, we may never fit each piece into the picture. Long after the case closes and the trial ends, specific questions relevant to evidence discovered may remain in the investigator's mind.

By applying the steps of the reconstruction process, the analyst may define more accurately those events associated with the incident. These events become the definition of the crime as a series of actions in which motivation, intent, or other subjective factors have no effect. The why of the event (e.g., *why* the subject chose to cut the victim three times) in no way affects the fact that the event occurred (e.g., the victim *was* cut three times).

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As simple as this seems, by sequentially ordering as many of the events and event segments as possible, the reconstruction takes shape objectively rather than subjectively. After we have defined all available events, what should not occur, but often does, are completely contradicting re-creations. In using this model, whether some particular event is favorable to the prosecution or defense is of no concern. If it occurred, and physical evidence exists to prove its occurrence, we cannot argue its existence. We can only reformulate our beliefs regarding how and why the crime proceeded as it did. Having defined the crime in this fashion, we may then turn to the more subjective issues and attempt to resolve them.

The model is just a concept for analysis — a process to apply to all information and evidence considered in the investigation. In the following section we will present a specific methodology to which we can apply that concept.

Event Analysis: A Process for Crime Scene Reconstruction

In event analysis, recall that the overall crime or occurrence is the *incident*. The incident encompasses all actions related to the occurrence. Within this incident there are specific *events*. Each event is some part of the occurrence. Each event is defined by small, specific actions taken that are in turn supported by the presence of specific items of evidence. Each of these smaller actions we refer to as *event segments*. Consider these events and event segments to be slices of the time window: moments of the incident defined by some physical action or form. Because the reconstruction attempts to define the crime or incident by establishing these events, we call the overall process event analysis. The steps taken to create a crime scene reconstruction using event analysis are as follows:

- Collect data and, using all evidence, establish likely events.
- Establish from the data specific snapshots or event segments of the crime.
- Consider these event segments in relationship to one another in order to establish related event segments.
- Order or sequence the event segments for each identified event.
- Consider all possible sequences and, where contradictory sequences exist, audit the evidence to determine which is the more probable.
- Determine the final order or sequence of the events themselves.
- Flow chart the overall incident based on the event and event segment sequencing.

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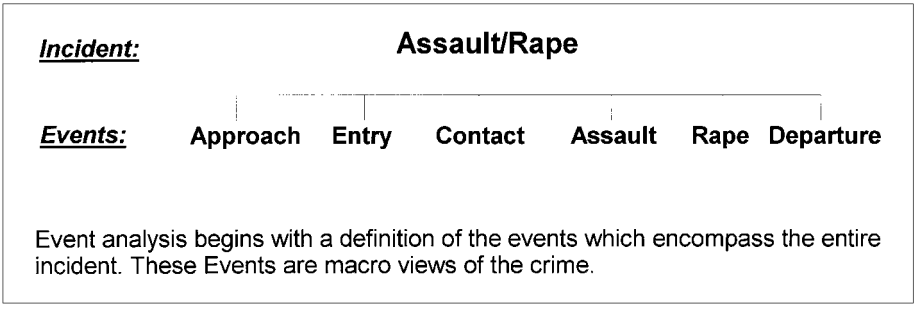

Figure 2.7 Establishing events requires that we consider what must occur for the incident to transpire. For instance, besides approaching and departing the scene, our subject must gain access to the victim and take control of her in order to commit the rape. Oftentimes the analyst can surmise these events before knowing detailed specifics of the crime.

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. The crime or *incident* encompasses all of these processes or events (Figure 2.7).

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, the rapist reaches through and unlocks the entry and climbs through the entry point. Each of these actions results in the creation of individual items of evidence. Our subsequent discovery and analysis of the evidence helps us establish that the event segments occurred. Examples of this evidence might be fingerprints on the outer surfaces of the entry point, glass fractures in the pane of glass, glass fragments on the subject's clothes and shoes, and dust footprints or disturbances in the broken glass where the rapist stepped.

As more and more of these event segments from the evidence are defined, they are considered in relationship to one another and the identified events (Figure 2.8). Based on these relationships, the various segments we believe are associated with a given event will be identified.

Our function now is to order, if possible, these related event segments. This ordering gives a structure and an understanding of how the specific event transpired. Again, all known information must be considered to place these segments in a logical and supportable order. Typically, very obvious beginning and ending event segments are found. There may also be several segments that fit together in a very logical and functional order as well as segments that appear to fit the sequence loosely, but we may be uncomfortable as to their

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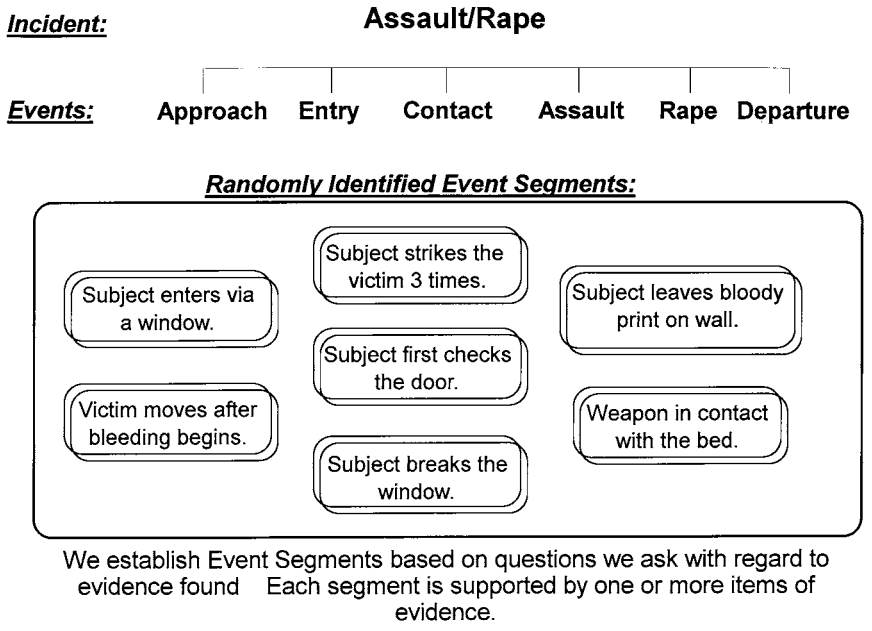

Figure 2.8 Event segments are "snapshots" of the crime. They detail specific actions and are based on our evaluation of specific items of evidence. Initially we may know only that they occurred, without understanding their sequence or relationship to the events themselves. Eventually the event segments will help define what actually occurred during any given event.

exact sequence. Of course we will also find segments we believe are related to the event, but for which we do not understand the sequence or order in any fashion (Figure 2.9). Ultimately, we will order and graph the information into a flow chart (Figure 2.10).

When considering all the information, remember too that each event or event segment has some action that either leads to or follows it. Nothing just happens. There is no "Beam me up, Scotty" as in *Star Trek*; our players must arrive, act, then depart. As an example, consider the rape/assault event of "break glass with crowbar." 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 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. Obviously, these issues become convoluted and lose relevance to the investigation as a whole; but if for some reason the issues were important, background evidence may well exist to support their occurrence.

Oftentimes the investigation will present the analyst with contradictory pieces of evidence that support two or more possible events, event sequences,

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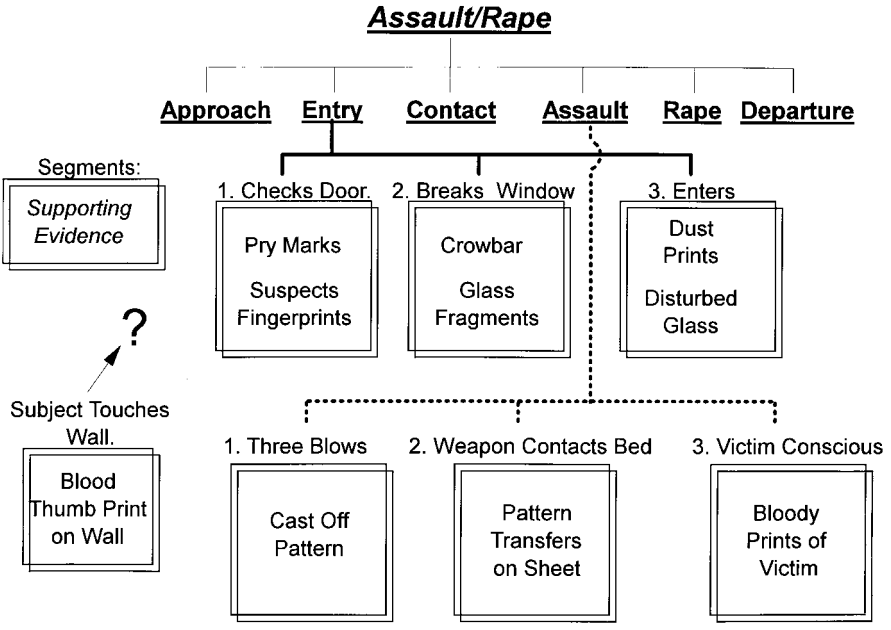

Figure 2.9 In time we seek to relate the event segments to a specific event and then sequence them. This gives us a clearer picture as to how the incident transpired. Not every segment will have a clear position in the reconstruction. For example, the segment related to the subject touching the wall might well belong to the assault, rape, or departure event; unfortunately, there is insufficient evidence to establish where it belongs in the overall reconstruction.

or event segment sequences. By looking at this background evidence, we can audit the crime to help establish which of the events or sequences is the more probable.

Consider a case 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 for the shooting. Testimony by the defendant indicates the shooting occurred at the first location (a bathtub). He claims he placed the weapon on the floor there and never again moved it. This information supports his overall claim of self-defense. 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. 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.

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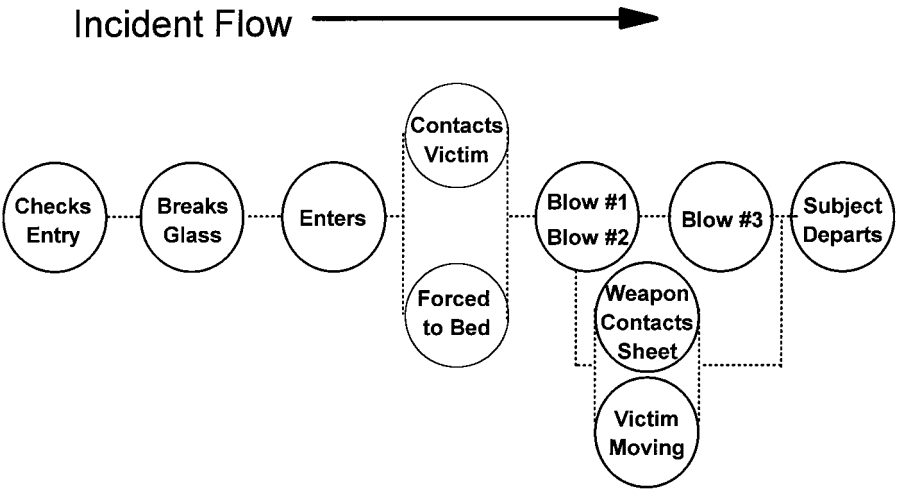

Figure 2.10 Event flow charting. Using a supportable order or sequence, we can lay out the events and event segments in a flow chart model. In effect, the flow chart is a graphic representation of the reconstruction.

- The shooting occurred where the subject 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 after the fact by the subject.

The analyst's issue becomes one of finding some means of deciding which of these possible events is more probable. 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 subject 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. The other evidence and facts support this claim. These stains are evident on all surfaces and objects present near the first location.

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 earlier event. If the subject is being truthful and Location 1 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.

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Unfortunately, our subject neither claims this, nor in his overall description had sufficient time to take such action. This precludes the pillow's presence at the first location before the shooting. As such, the more probable events are

- The weapon was moved from the first location, came in contact with the pillow at the second location, and was then returned.
- The second location is the actual site of the shooting.

Although auditing does not answer absolutely which event segment sequence is the actual sequence, it establishes that the subject's story, as told, is false 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.

Event Flow Charting: Demonstrating the Result

The final step in the reconstruction process is to order the events into a logical and supportable sequence, wherever possible. The information sought and developed during the assessment phase of the reconstruction will fuel the decisions the analyst makes at this stage. The process is best accomplished through the use of an event flow chart. Much as Rynearson and Chisum described for their "story-board," the event flow chart attempts to take each event segment and graphically orient it within the whole picture. Some analysts may feel this is an unnecessary step, as it is often possible to mentally orient a simple event into a functional sequence, but in a complex reconstruction the sequence quickly becomes confusing. By physically charting the event through the use of the event flow chart, analysts are better able to visualize the actual sequence, challenge their own theories, and recognize weaknesses or points where sequencing is just not possible.

The basis of the event flow chart lies in several previously developed investigative processes. The first is the investigative timeline. Rarely does a homicide investigator conduct a complex investigation without charting out a specific timeline, in which they detail known events and when they occurred. The investigative timeline in and of itself is extremely beneficial in evaluating investigative theories (Figure 2.11). A second link to the event flow chart is the ANACAPA "process" chart. This methodology was developed to teach an investigator to identify what steps a criminal would need to accomplish in order to carry out some ongoing criminal enterprise. Recognizing these steps allows the investigator to focus investigative efforts (Figure 2.12).

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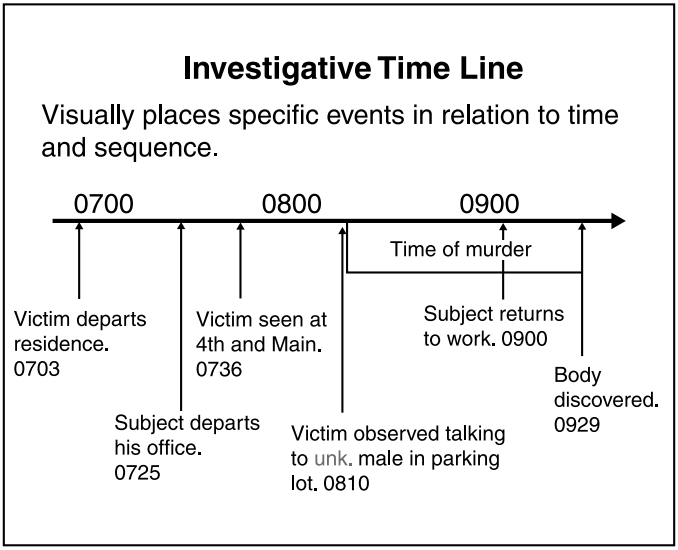

Figure 2.11 The investigative timeline is a widely used technique in complex investigations. It allows the investigator to graphically chart known times and the events associated with those times.

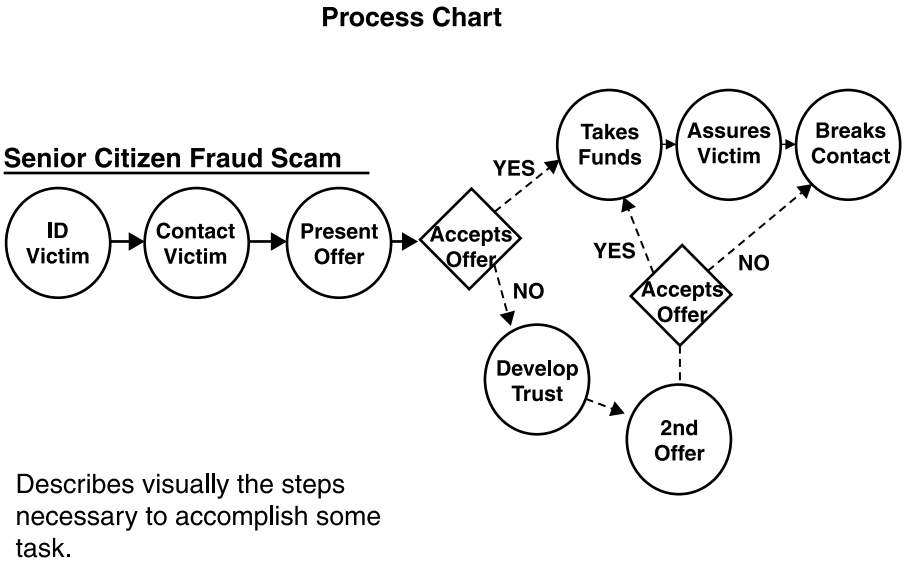

Figure 2.12 A process chart is used to analyze and identify the steps necessary to carry out some criminal enterprise. This technique is taught by ANACAPA Sciences. The example describes the steps necessary to carry out a fraud scheme.

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The event flow chart incorporates characteristics of each of these, in an effort to define and validate the ultimate sequencing of the reconstruction.

The event flow chart seeks to graphically visualize the reconstruction. Once developed, it is extremely useful for explaining and depicting the reconstruction to a jury, a counselor, or another analyst. As previously mentioned, it also serves immeasurably in allowing analysts to challenge their own theories and preliminary sequence. Very often analysts will not see logical flaws in the reconstruction sequence until it is graphically depicted, particularly in complex events. Once drawn out, however, these flaws are much more evident and it becomes easier to recognize that a specific event segment cannot precede some other segment. In preparation for trial and the dreaded cross-examination, one of the most effective methods available to the analyst is to study the event flow chart. The analyst can consider likely alternative theories and review details that refute such possibilities.

Developing the event flow chart is relatively simple. What the analyst chooses to show on the chart is case dependent. Options include charting the entire reconstruction or charting a specific area of the reconstruction that is in contention. In the following example a man was beaten in a ditch, where he died and was left. The assault occurred in a small, defined area. There is evidence that establishes the victim entered this ditch upright, but ends up in a semi-upright position just prior to the beating. The specific event considered in the example is, "Victim semi-upright in ditch, assault occurs." Six event segments were developed, relating to this event. They are

- Victim in a semi-upright position
- Victim does not move from this position
- Victim touches his hand to his head, transferring blood to the hand
- Victim receives three spatter-producing blows
- Victim is not struggling with anyone on the ground
- Victim rolls left to right, to his final position

To sequence and produce the flow chart, the analyst looks for the obvious starting and ending segments. One or the other, if not both, will normally be evident. In this instance, the event segment "Victim in a semi-upright position" is the obvious starting segment, whereas "Victim rolls left to right to his final position" is the obvious ending segment. The analyst begins by charting these segments (Figures 2.13 and 2.14). The event segment "Victim receives three spatter-producing blows" obviously follows the entry of the victim into the ditch; therefore, it is charted to the immediate right of our beginning segment (Figure 2.15). The event segment "Victim touches his hand to his head" must occur sometime after the blows, but we cannot state with any level of probability exactly when this occurred. Was it after the first blow, the second, the third, or just prior to collapse? We

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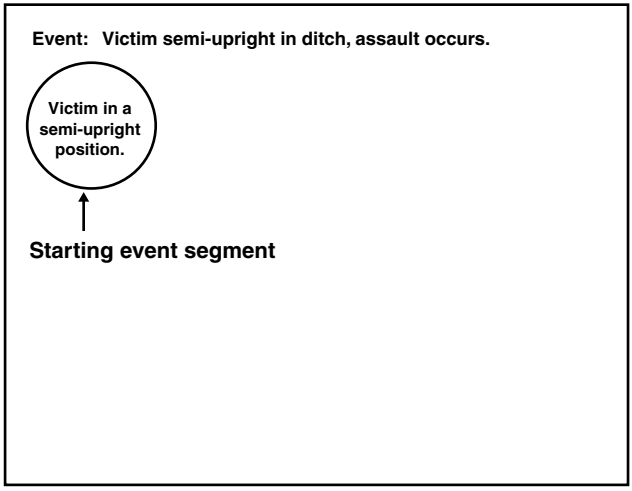

Figure 2.13 Within the identified event segments relating to any event there will be an obvious starting segment. The analyst charts this segment first.

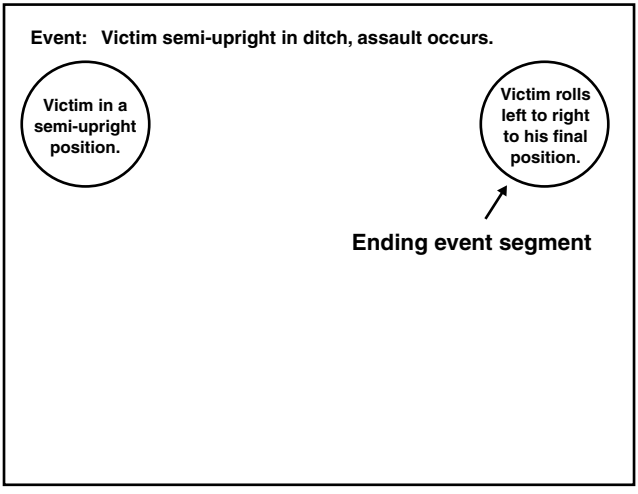

Figure 2.14 Usually an ending segment will also be obvious in the information. The analyst charts this as well.

chart it to the right, but remain cautious as we begin to include additional event segments (Figure 2.16). The event segment "Victim is not struggling with anyone on the ground" is another segment for which the exact sequence is unknown. There is spatter on the ground and leaves adjacent to the victim, yet the leaves and dirt are undisturbed. This demands that the segment follow the spatter-producing blows. What we do not know, however, is how "Victim touches his hand to his head" and "Victim not struggling" are

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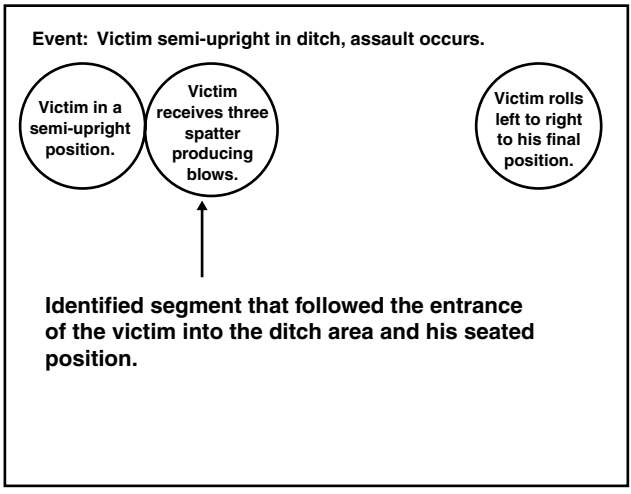

Figure 2.15 Segments that have a clear sequential relationship are charted next. The blows to the victim obviously followed his arrival in the ditch but preceded the other identified event segments in the example.

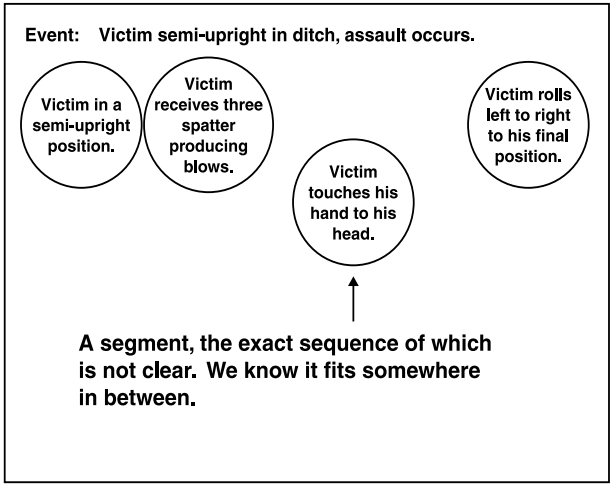

Figure 2.16 Other segments will follow logically but may not allow us to precisely determine where they follow. We chart them, but challenge their positions each time we add other segments to the chart.

sequentially related to each other. Therefore, we align them vertically in the chart, drawing dual arrows from "Victim receives three blows" to define this concurrent path. A similar series of arrows leads out of the two event segments to the ending segment (Figures 2.17–2.19). Our last segment, "Victim doesn't move from this position," relates to the fact that the victim entered the ditch and stayed in a very defined area throughout the attack.

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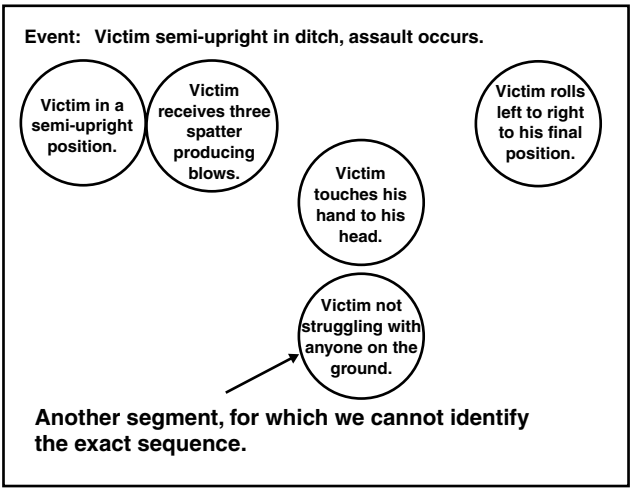

Figure 2.17 Unable to state how the segments "Hand to head" and "Not struggling" are sequentially related, we chart them together without alluding to any specific sequence.

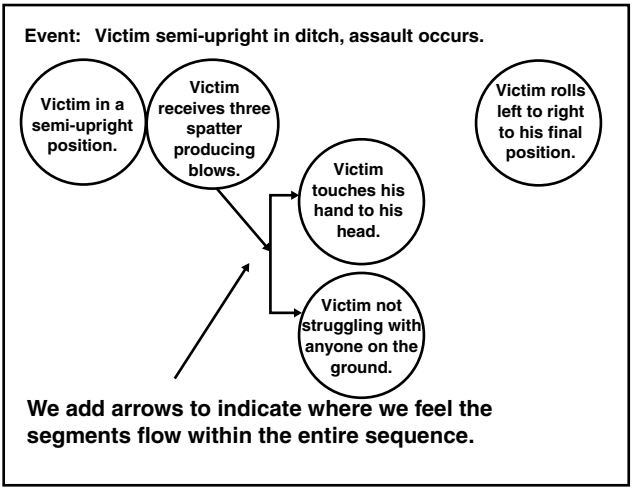

Figure 2.18 Arrows are added to demonstrate the relationship of both segments to the preceding segments.

Therefore, this particular segment encompasses the "…three blows," "…hand to head," and "… not struggling" segments. It then is offset, with arrows added accordingly (Figures 2.20 and 2.21).

The previous example is a small part (a single segment) of an actual reconstruction; it is quite simple and easily understood. However, the nature and orientation of the paths defined for any given event can become

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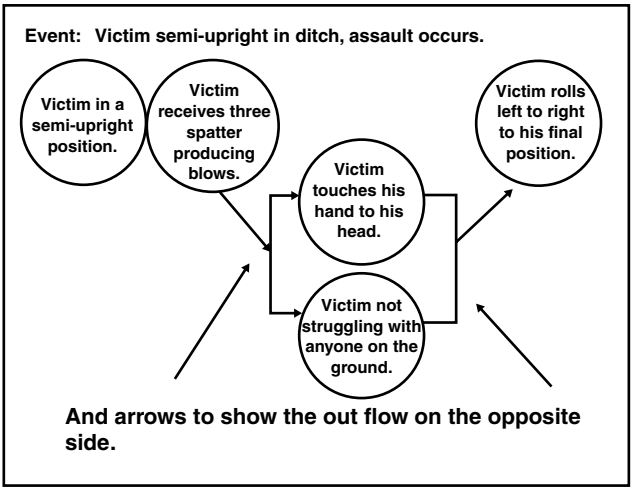

Figure 2.19 The addition of similar arrows demonstrates the relationship of both segments to the subsequent segments.

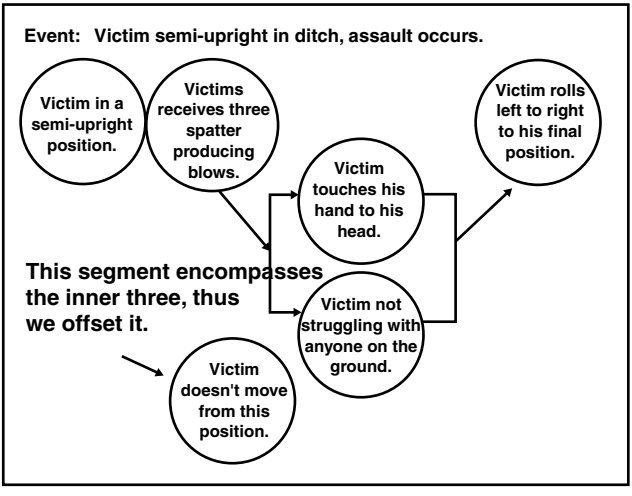

Figure 2.20 The segment "Doesn't move position" relates to a segment that occurs while three other segments are occurring; thus, we offset it.

extremely complex. A clearly linear path, in which one event follows another, one after the other, is rare indeed. More often than not we are dealing with dynamic events, with simultaneous event segments. The only recourse is to allow the paths to develop naturally. A typical mistake made by newly trained analysts is to force the event segments into a single linear path. Although it can be done, in effect it removes any value the flow chart had in detailing "how" the event took place.

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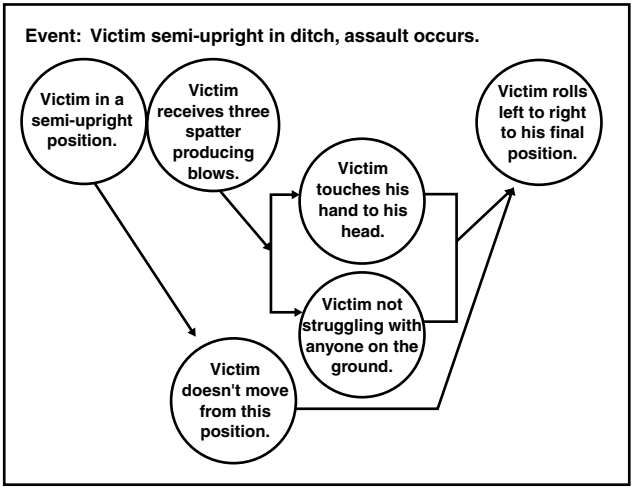

Figure 2.21 After offsetting the segment "Doesn't move position," we draw arrows accordingly, connecting it to the beginning and ending segment. The purpose is to demonstrate that it is ongoing as the encompassed events occur.

As the complexity of the event increases, separate paths often will develop for a given item or person involved. Figure 2.22 is another simple flow chart, but a good example of multiple paths of interest. The upper two thirds of the flow chart define event segments relating to the actions of the victim in the event. The row of event segments at the bottom of the flow chart defines what is happening with a weapon used in the event. At various points in the chart, lines show the concurrence of event segments between the two. This kind of complexity is likely to develop if an event involves multiple weapons, subjects, or victims. In such instances the effort required to make the flow chart orderly will tax even the most patient analyst. A practical approach for developing the flow chart is to place each event segment on a self-adhesive memo and then orient the segments on a wall or foam board. As the flaws are recognized and an orderly layout sought, this method makes it easy for the analyst to reorganize the information.

In the end, the result of the event flow chart may look something like Rynearson and Chisum's story-board or an ANACAPA Sciences Inc. process chart. With all the time windows or snapshots sequenced, we define the crime in as much detail as possible. Of course the ordering may not be as simple as our illustration. The end result may have many segments for which we are unsure of their sequence.

In considering the entire process of event analysis, it's important to keep two issues in mind. First is the "generalist" view for analysis and the second is flexibility.

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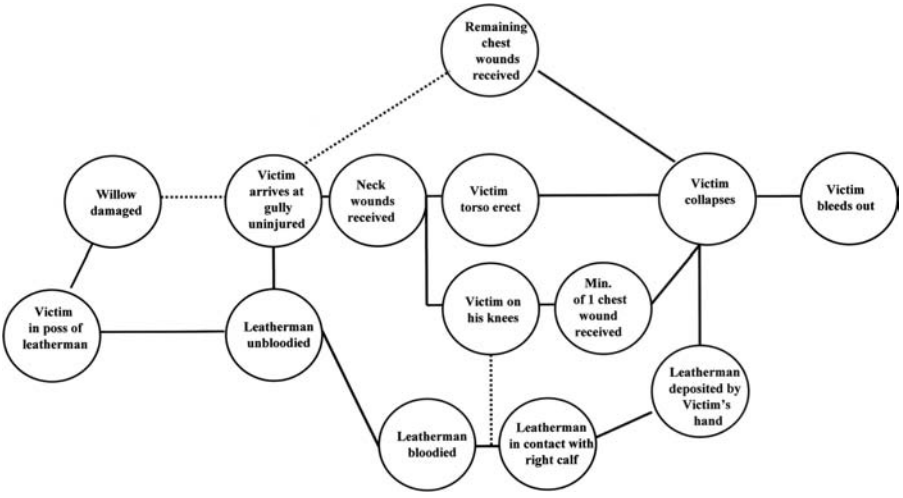

Figure 2.22 A case example of a flow chart. The chart has two specific paths that naturally developed. The upper two thirds follow the actions of the victim, whereas the lower third tracks the weapon involved. The connecting lines and chart position show how the two interrelate sequentially in this instance.

To revisit the "generalist" viewpoint, remember that the crime scene analyst cannot be an expert in every forensic field. Yet, any forensic field may establish some part of the event segments. To conduct an analysis the analyst must have a strong working knowledge of the major forensic disciplines, including crime scene processing.

The entire investigative package consists of information and efforts emanating from the crime scene processors, investigators, and forensic scientists of every nature. Their products contain varying expert opinions, reports, and the scene evaluations. Someone must apply all of this knowledge to the incident and mold from it the best view or most probable definition of the crime. This role should and must fall to the analyst, who has both a criminalistics background and investigative experience.

The second consideration is that of flexibility. As we acquire new evidence we must reevaluate the entire event sequence, or a specific segment based on that new information. Remember that no matter how detailed we may be, we will never have a "standard" of our crime to which we can compare our analysis. We need to be ready to wipe the slate on a particular sequence order if we discover contradictory physical evidence.

In the end, it is the evidence at the crime scene and our application of event analysis to that evidence that allows us to set a foundation for the crime. On this foundation we can ultimately build our understanding of the case using the more subjective information discovered during the investigation.

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The Role of Logic in Analysis

John Locke in *An Essay Concerning Human Understanding* remarked, "God has not been so sparing to men as to make them barely two-legged creatures, and left it to Aristotle to make them rational." Locke believed the study of logic and reasoning served no function, that man was a rational creature by nature.

We recognize reasoning and critical thinking as skills used to resolve problems encountered daily. They provide a practical approach by which analysts weigh options and ultimately make conclusions about events they were not present to observe.

Much as Locke believed, the application of a raw talent may be sufficient in some instances. Yet, by refining our reasoning skills and recognizing the dynamic nature of the events we seek to explain, we strengthen our ability to define the most probable conclusion. Therefore, it is important for analysts to consider logic and reasoning as they relate to the reconstruction task. As Dr. Jon Nordby stated: "The purpose of the expert is to refine the context of the situation using the expert's understanding."[37] Let's explore the application of logic and its purpose in refining this "context" during the process of crime scene reconstruction.

Expectations and Predictions

Every day of our lives we encounter situations in which we have expectations. We expect our positions to await us at work or we expect to receive a handshake when we offer one. Although subjective, we base these expectations on experience. In any situation, the expectations or context we have (which we base on our personal experience) influence our perceptions and observations in that situation.[38]

As investigators we also have expectations and a context of observation. The moment we walk into a crime scene our mind begins to process data. The context and expectations we apply play an important role and help define our early investigative focus. For example:

- The room is locked from the inside. Was this a suicide?
- That looks like a high-velocity spatter pattern. Where is the gun?

Such expectations are usually the result of study and personal experience. They typically serve the function of providing initial momentum to an inquiry and may guide us in the investigation.

Unfortunately, these expectations are nothing more than simple *predictions*. As predictions, they may prove to be without factual basis. Dr. Nordby, in this regard, writes, "Inappropriate expectation laden observations can lead

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to observation errors. Recall that nothing is self evident unless the detective happens to be looking for it."[39] As we discussed in the assessment role, the investigator may need to ignore early beliefs or concerns if evidence to support such beliefs is not forthcoming. Flexibility must be a cornerstone of the investigator's approach.

Consider this concept of expectation-laden observation in relation to a teaching incident. While instructing a bloodstain course in Helsinki, the author was asked to explain a pattern the students had created while completing an impact spatter experiment. Present on the target was a somewhat U-shaped void in the middle of the pattern. In examining the pattern, the author considered the experiment as he had explained it to the group, yet he could not immediately explain the void; the instructor's expectation was that the group had used the targets, blood, and mousetrap as told and somehow managed to cause the pattern. In reality, the students introduced another element into the experiment by taping a balloon onto the target area.

The instructor's expectation was simple: they were students, they were told to do something specific, they had always done so before, so the situation could be explained given these circumstances. Such expectations created a type of tunnel vision, which precluded just asking, "What did you use to cause the void?" Expectations guide the analyst, but they must always be viewed in their proper light. They are not absolute, and they may severely limit our thinking.

Impact of Dynamic Events on Reconstruction

The dynamic nature of our world also affects our reconstruction attempts. By dynamic we mean simply that in any event there are countless ways in which two components may interact. In essence, a reconstruction tries to establish a previous state of a set of components. Our ability to define this previous state is directly related to our ability to determine the relative positions and interactions of the components. Our typical components are the victim, subject, weapon, and blood. We may be able to infer the velocity of the weapon, and we know that gravity and air resistance have a constant effect on the blood in flight. Unfortunately, the nature of how the components interact (e.g., exact positions of victim and subject, the angle of the weapon striking a body) leave a lot of room for error in defining their specific motions. Because we will never define in absolute detail the positions and actions of these components, we are likely to limit our conclusion and reconstruction to general parameters of possible and impossible events.

This issue directly affects experiments in which we try to replicate bloodstain patterns. Imagine a recreation attempt of a simple hair swipe. To absolutely reconstruct the swipe we would need information pertinent to exactly how many hairs were bloodied, by what volume of blood, and in what order

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and at what angle they contacted the surface involved. Given the detail required, it is unlikely our attempt at a pattern recreation will produce an exact copy of the original stain. It is far more likely we will only create an approximate simulation, the specific characteristics of which may or may not "match" the stain in question. Again we must emphasize that no one has an ability to define in absolute detail the specifics of such dynamic events! Those who would claim to do so should seriously reconsider their positions.

Deductive vs. Inductive Reasoning

Sir Arthur Conan Doyle's fictional character, Sherlock Holmes, often utilized complex reasoning to reach his investigative conclusions. In truth, the manner of reasoning used by the fictional master of deduction was often more inductive than deductive. This distinction is of little importance in fiction, but to the investigator the difference is real.

Deductive and inductive arguments may appear on the whole as similar. There is, however, a distinct and important difference in the conclusions that follow each. Deductive arguments are those in which the conclusion must logically follow from the premise. If the premise is true, the conclusion *must* also be true.

> **Premise:** Several fingerprints, in Person A's blood, are on a knife. The prints belong to Person B.
> **Conclusion:** Person B was in contact with the knife after Person A began to bleed.

The premise establishes all information in the conclusion. The conclusion must therefore be true. It does not exceed the knowledge presented in the premise.

Inductive arguments, on the other hand, allow for exploration by the analyst. If the premises are true, the conclusions are also likely to be true. As Morris Engel explained in his book, *With Good Reason*, "The conclusion is presented as following the premises with a high degree of probability."[40] Accepting the previous deductive argument and its conclusion, let's expand the situation.

> **Premise**: Person A was stabbed at Point Z. The knife containing the incriminating print was also found at Point Z.
> **Conclusion**: Person B was involved in the assault of Person A.

On the surface, the basis for the argument looks sound. If the premise is true, it is probable the conclusion is true. The conclusion, however, contains information not completely established by the premise. An obvious possibil-

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ity is that Person B found Person A after the assault and then touched the knife. Although the argument and the conclusion may well be true, the inductive nature causes the conclusion to exceed the knowledge presented in the premise.

In analysis, we must distinguish deductive arguments from inductive arguments. An inductive argument is a valuable tool for investigators, leading to that which is not always apparent. We cannot, however, treat an inductive argument as a deductive argument because this excludes possibilities and leads to unsound reasoning. Far too often in crime scene and bloodstain pattern analysis, investigators accept inductive arguments as deductive and define too narrowly the likely events in their reconstruction of the crime.

Informal Fallacies Encountered in Analysis

Any analysis, at its heart, is an argument. Before we accept any argument, we should be clear on three things:

- What does the argument choose to establish?
- Is the evidence presented correctly, without weighting in either direction?
- Is the reasoning of the argument valid?[41]

There are three categories of fallacies that deal with these questions: fallacies of ambiguity, fallacies of relevance, and fallacies of presumption. Although we may encounter any of the fallacies, the presumptive fallacies tend to be more prevalent in our discipline. This group deals with incorrect arguments disguised to look like correct arguments. The following represent a sampling of such fallacies and illustrate their deceptive nature.

The first presumptive fallacy we will discuss is bifurcation. It presumes that something either is or is not true. There is no in-between. Lawyers who ask us to "just answer yes or no" use this fallacy in their favor. They know the witness cannot always adequately answer all questions so easily. This allows the lawyer to receive the answer he wants, without delving into background detail that might better reveal the truth of the matter. Analysts have a bad habit of accepting or including bifurcated positions about events and event segments in their reconstruction without supporting evidence; rarely is such a position warranted.

Sweeping generalizations are another fallacy of concern. In this case a rule that is applicable in some instances is applied to all instances. For example, a well-intentioned bloodstain axiom states: "Correct interpretation of the spattering of a bloodstain is *impossible* [italics added] without first considering surface texture of the target upon which it impacted."[42] Although in many instances the analyst must consider surface texture to

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properly understand a pattern or stain, this axiom is certainly not true for every instance. Specifically, in determining directionality of the stain, surface texture will not in and of itself affect the conclusion drawn. Thus it is possible to correctly interpret a bloodstain in this regard without considering surface texture.

As an example of a combined argument (both a bifurcated argument and a sweeping generalization), imagine a question about the origin of a spatter following a gunshot. We know that shotguns often produce considerable back and forward spatter. Having found a small stain that is consistent with a gunshot spatter, must we exclude it from having been produced by the shotgun simply because it is not large? Analysts have argued exactly that, claiming that shotgun wounds produce only large spatter patterns. A less presumptuous position demands we look at the empirical data. Gunshots, to include shotguns, do occur where there is little or no spatter. Between the parameters of "a lot" and "very little" reside many possibilities. The sweeping generalization attempts to apply a general rule (e.g., shotguns often produce large stains) to every situation. The bifurcated position bolsters the argument (e.g., shotguns produce only large stains) to make it look incontestable.

The ultimate issue — that is, Can a small spatter stain be produced by a shotgun? — remains unanswered based on this information alone. Is it possible to produce such a stain by firing a shotgun? Yes. Obviously, it is not the most frequently occurring event, but the argument uses the bifurcation and sweeping generalization position to force a decision on the issue without exploring the possibility.

Another fallacy encountered in crime scene analysis is that of false cause. In these instances the analyst draws a causal connection between two actions or an action and some item of evidence. Consider arriving at the site of a homicide and discovering bloodstains of various types. We observe the victim and note wounds that might account for these stains. If we simply assume all the stains to be the result of the victim's injuries, the fallacy of false cause has presented itself. We have not considered the possibility that other people (particularly the perpetrator) were injured and then created the stains. Using other evidence, we may reach the same conclusion later, but at this point the argument is unsound.

An irrelevant thesis is another fallacy encountered. Simply stated, an irrelevant thesis attempts to prove something that is not at issue. It is then offered as proof that another issue is false. Imagine the following question: Could Event A create Bloodstain Z? The answer is likely to be put forth as a "yes" or "no." The irrelevant thesis answers this question by offering an alternative set of circumstances, Event B, that could also create Bloodstain Z.

The most deceptive aspect of an irrelevant thesis is that it may offer valid information that could be of importance to the investigation. Yet the

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approach veils the answer in such a manner as to exclude or rebut the original issue without having dealt with it at all. Whether Event B could produce Bloodstain Z says nothing about the question of whether Event A could produce Bloodstain Z. Although Event B may well be the circumstance that produced the stain, it does not disprove Event A in and of itself. Event A must still be considered and either excluded or included based upon the evidence available.

We have discussed only a few of the logical fallacies; there are others. To properly conduct analysis, analysts must consider the nature of the arguments they attempt to support or rebut. Although the analyst may not know or remember the proper names of these fallacies, our point is simple: to be accurate, the analyst must recognize and eliminate erroneous arguments. Critical thinking is the key to analysis.

Putting the Pieces Together

The limitation in the reconstruction task is 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 they 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 such as, "That's not logical. Why would he do that?" begin to appear. It is not that we aren't concerned with motive, 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.

In most instances, the deceptive nature of the fallacies and subjective traps discussed occur without intent on the part of the investigator or analyst. We all are capable of these failures and fall prey to unsound reasoning as a matter of our basic human nature. To avoid these subjective traps, analysts must try to understand a basic application of logic, then seek to define their arguments using acceptable reasoning. The basis of our ultimate reconstruction conclusion rests on earlier conclusions made about items of evidence. Point A leads to Point B, which leads to Point C, ad infinitum. If we infer Point A based on poor reasoning, we may taint the entire conclusion. As such, the conclusion could also be wrong. Only with clear, logical thinking are we likely to stay the course and reach acceptable solutions.

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Given the dynamic nature of our world and its interactions, no one can establish every action related to a crime with certainty. Paraphrasing Voltaire, only a charlatan is absolutely certain of everything. We must recognize that although they are valuable tools, our expectations or predications are subjective in nature. As such they cannot form the cornerstone of our conclusions. We must follow a proven path of evaluating the evidence present in our scenes, using the scientific method, and applying formal event analysis whenever possible. To accomplish this, reconstructionists must refine their context of observation, which they do by "assess[ing] the entire scene, noting all competing explanations [and] refusing to be guided by inappropriate preconceived expectations."[43]

In this manner our crime begins to emerge as a series of objective moments, which we then link and sequence to produce the most probable view of events that encompass the incident. Once it is 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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Terminology

3

There are several schools of thought on the use of "technical" terms for bloodstain pattern analysis. One voices the concern that in using these terms the analyst may well alienate the intended audience — the jury. Such analysts speak in layperson's language so that the jury is neither offended by their expertise nor lost by the subject matter itself. A second position argues that analysts, being analysts and being accepted as knowledgeable in their trade, must speak in a manner that conveys that knowledge. Technical terminology is simply another way of exhibiting ability.

The two positions present a classic bifurcated argument, in that neither is totally wrong nor completely right. The possibility of alienating the audience is real and must be considered when testifying. Yet the discipline has a generally accepted vocabulary that is relatively clear and concise. Failing to use the accepted vocabulary could easily damage the credibility of the analyst because the opposing counsel may try to imply that speaking as a layman indicates a lack of knowledge in the subject matter.

Between these two positions lies the ability of the analyst to use a combination of layperson's explanations along with an underlying infrastructure of technical terminology, skillfully taught and explained beforehand to the jury.

The analyst gains several things through this process. First, the analyst's credibility is better established by the use of "technical" knowledge. This applies not only to courtroom situations, but also in dealing with other investigators and analysts. Understanding and accurately using the accepted terminology of the discipline eliminates the ability of anyone to disparage the speaker.

Another positive aspect in using such terminology is that the process of testifying becomes easier. Once introduced, a term does not change in definition. Explained in detail to the court, a term such as swipe is easily brought back to mind by gentle reminders of the previous discussion. As the jurors begin to grasp the vocabulary, they too may feel more confident in their own

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ability to understand the testimony. As is often the case with expert testimony, the courtroom becomes a classroom.

The reader must accept, however, that no strict set of terms is available. Unfortunately every analyst has a way of adding and customizing those terms in use. In this chapter we offer our own perspective of terminology. This terminology should not be construed as all inclusive or absolute.

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 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, some subjective, others not so subjective.

Analysis implies a structured approach in evaluating that which is to be examined. Analysis is a detailed examination 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, must the bloodstain pattern analyst examine the physical nature of stains. It is not that acceptable "interpretation" of a crime scene is bad, it is simply that we need to exclude, whenever possible, references to actions that can be construed as subjective and therefore unscientific.

There is a reason to use *pattern* vs. *spatter* or *splatter*, because technically analysts evaluate all types of bloodstain patterns. Spatter is a very specific type of bloodstain pattern; properly, a bloodstain spatter analyst would be one who analyzes only spatter. Bloodstains found at scenes of crime run the gamut for their source of origin. Stains such as swipes, pattern transfers, or blood pooling are not technically spatter. Thus, a bloodstain pattern analyst examines patterns of bloodstains in detail to determine their nature and interrelationships, no matter what their source.

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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 is used singularly as a verb, whereas spatter is used 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 the analyst in understanding and conversing in the discipline of bloodstain pattern analysis. Although perhaps not absolutely complete, they certainly serve as a basic vocabulary for anyone interested in the discipline.

Grouping Stains

We can group bloodstains into three general, basic categories: passive stains, transfer stains, and projected or impact stains. This categorization was originally suggested by Jozef Radziki.[2] A fourth category might be a miscellaneous category for those stains that do not fit neatly into Radziki's grouping (Figure 3.1).

Passive stains include clots, drops, flows, and pools. Impact stains include patterns such as spatter, splashes, cast-off stains, and arterial spurts and gushes. Transfer stains include wipes, swipes, pattern transfers, and other contact bloodstains.

These groupings allow a basic categorization of a stain or pattern for purposes of discussion early on in the investigation. For the long-term purpose of analysis, of course, a more specific categorization is necessary.

Angle of Impact

The acute angle, as viewed from the side, created by the intercept of the target by the droplet's vector (Figure 3.2)

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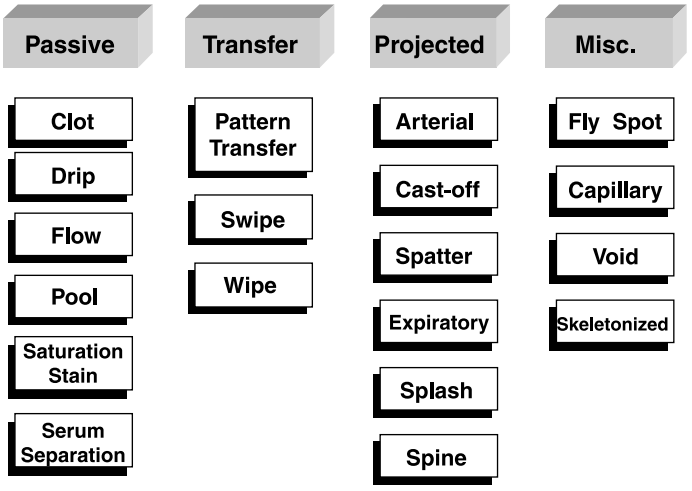

Figure 3.1 All bloodstains generally fit into one of four categories: passive, transfer, projected, and miscellaneous. This grouping was first suggested by Radziki.

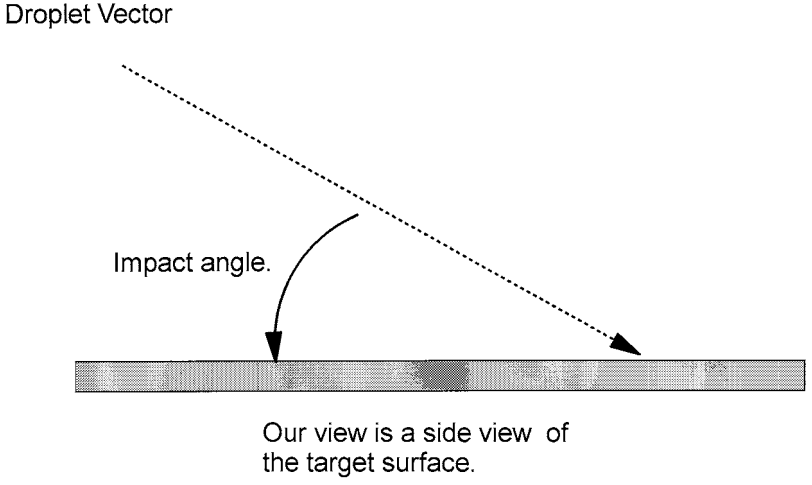

Figure 3.2 Impact angle. The acute angle (less than 90°) at which a droplet strikes a given target.

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 downward and impacting the floor have an impact angle of 90°. Drops traveling across the room 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 point of origin

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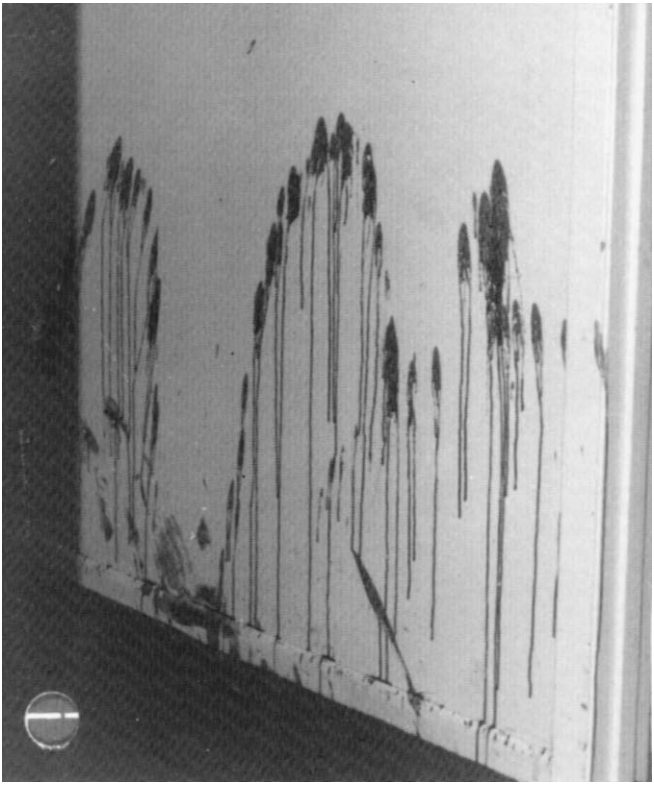

Figure 3.3 Arterial spurt. The rise and fall of the blood pressure is evidenced by the arc of the pattern.

for the stains evaluated. It is imperative in considering these issues that one remembers the angle of impact is relative to the target at the moment the blood impacts.

Arterial Gushing and Spurts

The escape of blood under pressure from any breach in an artery or heart, showing pressure, pressure fluctuations, or both (Figure 3.3)

Blood in the arteries flows under greater pressure than blood in the veins. If an artery is breached through some wounding mechanism while the heart is functional, the resulting pattern will very 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.

Arterial gushes are large-volume patterns in which the pressure variations are less distinct due simply to the volume of blood gushing out of the wound (Figure 3.4). Arterial spurts usually represent a smaller volume (volume refers

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Figure 3.4 Arterial gush resulting from a gunshot wound to the femoral artery.

to the amount of blood escaping the wound at that particular moment, not the total volume lost).

The most typical arterial 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.

In instances where the artery spurts directly into the target, the patterns found may appear as a meandering trail with many spines (Figure 3.5). The pattern is similar to that encountered when one directs a stream of water into dirt.

Atomized Blood/Misting

Bloodstain patterns characterized by a mist-like appearance, which are generally associated with explosive force such as a gunshot (Figure 3.6)

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 stain. 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

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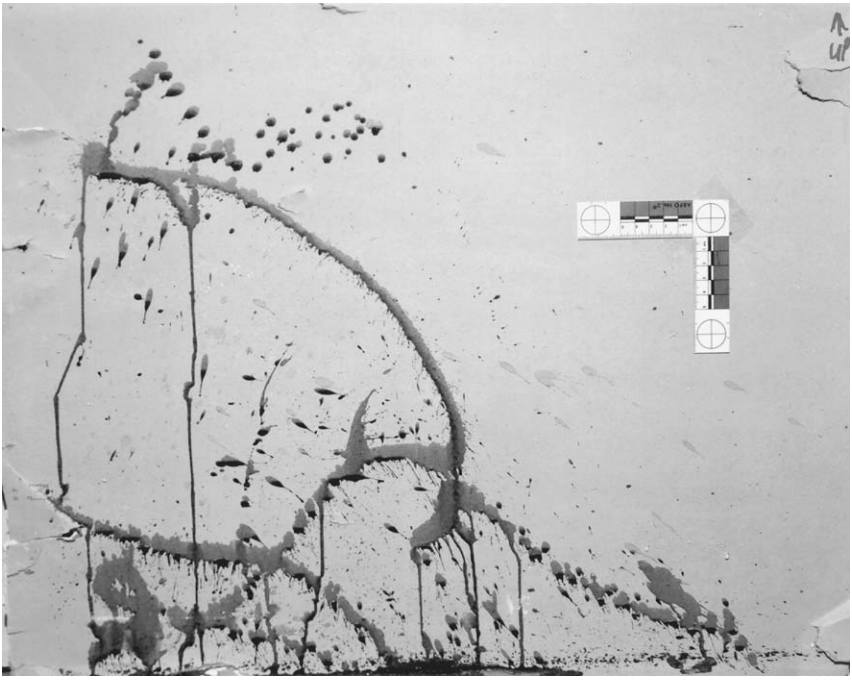

Figure 3.5 Arterial spurt resulting from a cut carotid artery. In this instance, the blood was projected more directly into the target, resulting in the "trail" appearance. Still evident in the stain are spines (indicating the force of projection) and several small indications of pressure fluctuations. (Photograph courtesy of Daniel Gilliam, Larimer County Sheriff's Department, Colorado.)

overall pattern, producing an area that appears as a reddish hue (Figure 3.7), 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 depends on 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 energy or force applied to the blood source increases, a decrease will be observed in individual stain size. Typically the overall diameter of such stains will measure a fraction of a millimeter.

Spatter

Stains created as a result of some impact

There are two types of spatter: forward and back spatter. The impact, whatever its nature, causes a breakup of the blood at the source into smaller droplets (impact spatter). In contrast, blood droplets that simply fall as a

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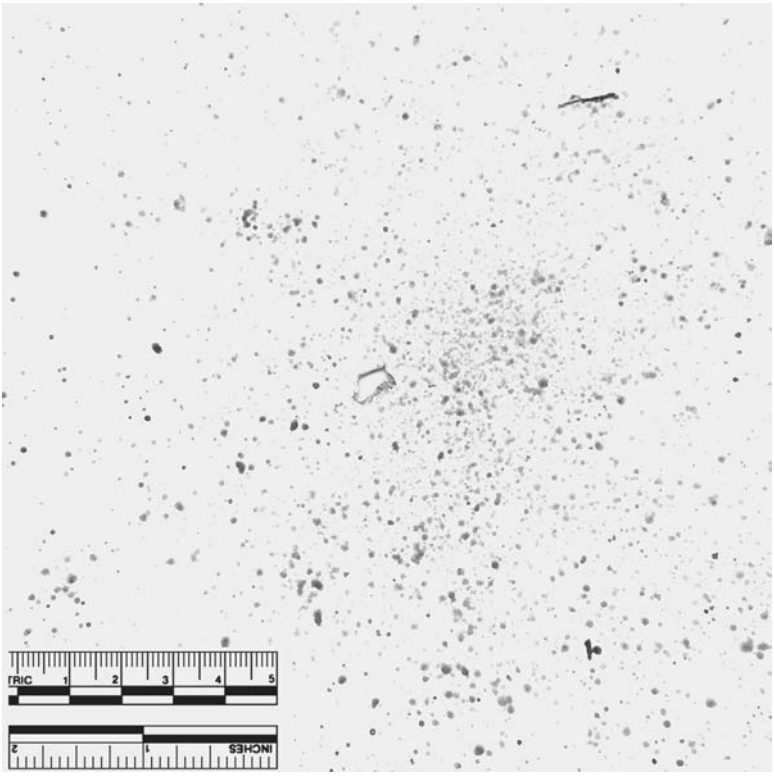

Figure 3.6 Atomized blood. The central area of the pattern surrounding the bullet hole exhibits a "misting" effect.

result of gravity, as in venous bleeding (often referred to as low-velocity stains), are stains, not spatter.

In instances where impact spatter is produced, the spatter projected outward, away from the item creating the force or energy, is considered to be forward spatter. Back spatter is obviously spatter that is projected to the rear or back toward the item creating the force.

The size of the spatter depends on the nature and force associated with the impact. Although not an absolute, back spatter will generally consist of fewer stains and slightly larger stains than those present in forward spatter. This is particularly true in instances of impact spatter created by a gunshot. On impact, a projectile creates a conical path of particles that expands out from the impact site. Blood and tissue are projected along this path, not only in the direction of the projectile but also rearward toward the source of the projectile.[3] The width of both paths expands as the distance from the impact site increases. The effect is similar to that observed in gunpowder residue deposits.

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Figure 3.7 A misting stain associated with a gunshot. Just below the locking mechanism of the door is an area saturated with small stains.

In these situations the majority of the projectile's force is concentrated along the vector of the projectile, resulting in the tendency toward a more symmetrical and intense pattern in the forward spatter. The forces causing back spatter are still considered questionable, but one may be the collapse of the temporary wound cavity created in the wound track.[4] These forces are not as intense as those present in the projectile itself, resulting in less breakup and less blood being projected rearward.

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** (Figures 3.8 and 3.9)

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. Serum separation is often observed late in the clotting process. At this stage a straw-colored liquid is evident

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Figure 3.8 A clot mass on a carpet, laying adjacent a bullet casing.

around the congealed mass. This serum is simply plasma without the blood solids.[5]

Capillary Action

> **The force exhibited in the attraction of a liquid to surfaces it is in contact with 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.

The first is the action evident when two objects in contact are separated, while blood is in between. An example may be 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 that 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. Figures 3.10 and 3.11 demonstrate this action, and Figure 3.12 shows the result.

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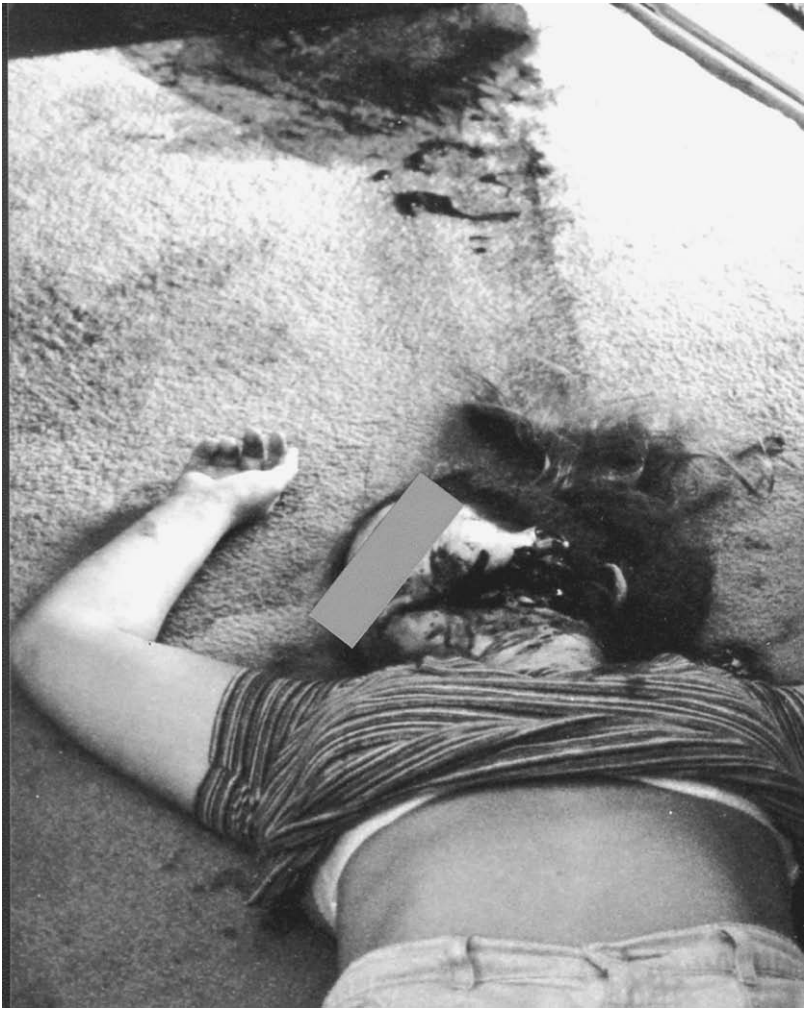

Figure 3.9 Clotted blood along the path of a wipe mark on carpet. The clots resulted from the movement of the victim after the blood pool had formed. The disturbance evident in the pool and clotted material helps sequence the events. (Photograph courtesy of Sgt. Louis Laurel, Attorney General's Office, State of Texas.)

A second usage encountered is to describe blood flow around objects. An example might be 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.

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Figure 3.10 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 3.11 Here the bridging of the liquid between the two surfaces is even more evident. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

Cast-Off Stains

Stains created when blood is flung or projected from an object in motion or one that suddenly stops some motion (Figure 3.13)

The pattern, referred to as a cast-off stain, is the result of blood being flung from some secondary object. This object may be a weapon (e.g., a club or hammer) or perhaps the victims or subjects themselves (e.g., a hand or hair). Cast-off stains create linear patterns that reflect the general position of the item from which they were flung; they may identify at least the minimum number of blows struck, and will likely provide some information as to the direction or motion involved in their creation.

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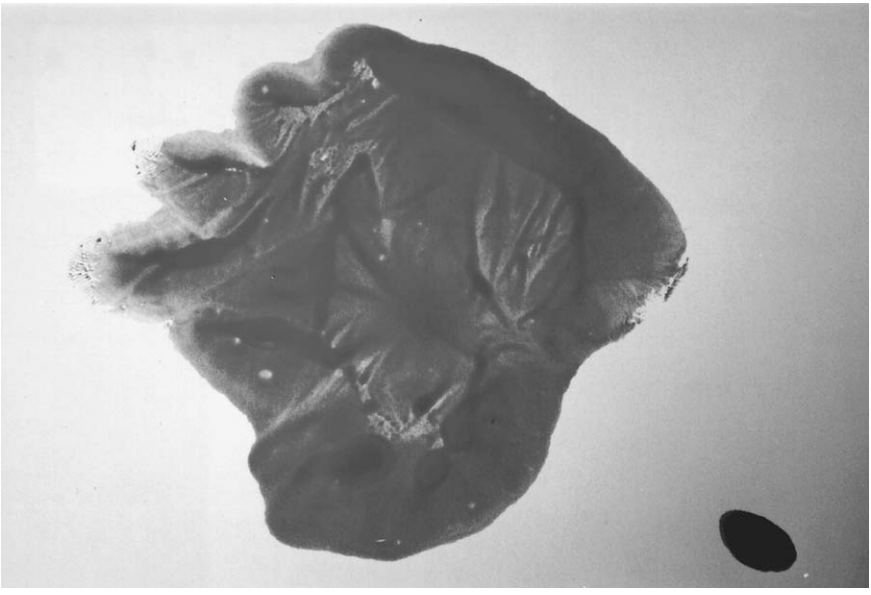

Figure 3.12 The result of Figures 3.10 and 3.11. Distinct linear features are present in the pattern as a result of the capillary action. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

The size of the cast-off stain will most often be smaller than those found in a drip stain. In a drip, the weight and volume of the blood collecting at the drip site will eventually overcome the surface tension, affected simply by gravity. In a cast-off stain, motion in the form of centrifugal force carries the blood out and away from the object. Once set in motion, the level of force present is more likely to overcome the surface tension earlier, resulting in smaller-volume drops. Cast-off patterns are discussed in greater detail in Chapter 8.

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.

Directionality is evidenced by a tail that is often created by the impact of the droplet. In all instances except satellite spatter, this tail points in the direction of travel of the droplet. Figure 3.14 depicts spatter showing indications of opposite directionality.

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Figure 3.13 A cast-off pattern. The distinct linear pattern on the right exhibits a motion moving up the wall.

Directional Angle

> **The angle, as viewed from the front of the target, between the long axis of the stain and a standard reference point** (Figure 3.15)

The directional angle defines directionality of a droplet in relation to the target. This is measured as a degree for the purpose of defining the flight path using forensic software.

Drawback/Blowback Effect

> **The process by which blood is deposited inside the barrel of a weapon after discharge** (Figure 3.16)

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Figure 3.14 A spatter pattern exhibiting two different events originating from opposite directions.

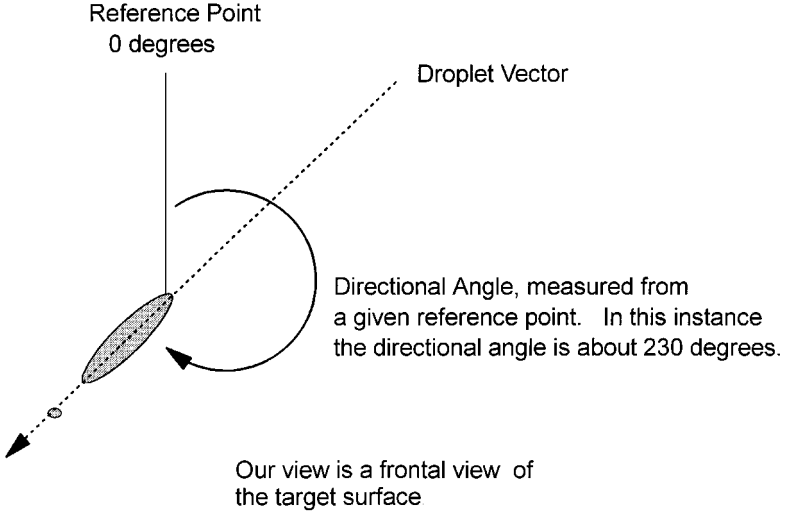

Figure 3.15 Directional angle. The angle between the long axis of a stain and a standard reference point. This angle describes the directionality, but does so from a standard reference point, thus allowing it to be used by forensic software.

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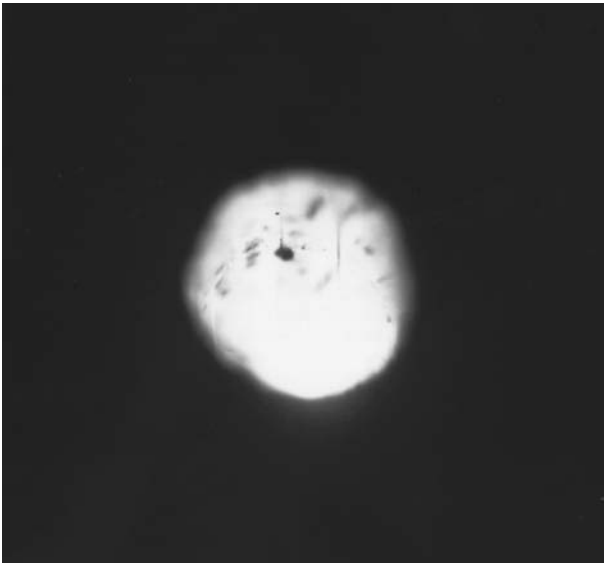

Figure 3.16 An example of drawback effect. Stains are evident in the barrel of this .357 revolver. The weapon was used in a suicide, with hard contact to the head. The photograph was taken using a fiber optic light, which was inserted into the breech of the barrel. (Photograph courtesy of Don Blake and Bill May, Norman Police Department, Oklahoma.)

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 drawback effect. Whether drawback is directly related to back spatter is still questionable. Most explanations have been based on claims that an overpressure 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. Probable correlations to the temporary wound cavity and the creation of back spatter are likely. 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.[6]

Drip Patterns

A pattern of blood caused when liquid blood drips into another liquid (Figures 3.17 and 3.18)

In instances where blood drips into standing blood (particularly in instances of pooled blood), a specific pattern is created. These patterns have characteristic traits whether found on vertical or horizontal surfaces.

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Figure 3.17 A drip pattern. Note the small, irregular drops among the larger drops. These are the result of satellite spatter projected out by the liquid-to-liquid impacts.

When created in proximity to a vertical surface such as a wall, a voided area may be found in the pattern on the wall. This pattern resembles a funnel or is V-shaped. On a horizontal surface the drip pattern causes random, somewhat irregular stains all about the pooled or standing blood. If these satellite stains from the drip pattern intermix with impact spatter it may be difficult to differentiate between the two. Chapter 8 discusses drip patterns in greater detail.

Expiratory Blood

Blood forced from the mouth, nose, or respiratory system under pressure, resulting in spatter (Figures 3.19 and 3.20)

In situations that result in mouth, throat, or lung injuries a spatter pattern is often created that may mimic impact spatter from other circumstances. The mechanical process of breathing acts on the blood as it is introduced into the airways of a living victim. The blood is broken up into relatively small stains. The process is analogous to an atomizer, which creates a mist by forcing out liquid using air pressure. Coughing, gasping, and the basic nature of the victim's breathing pattern obviously affect the nature of the air pressure involved, which in turn affects the appearance of the resulting stain.

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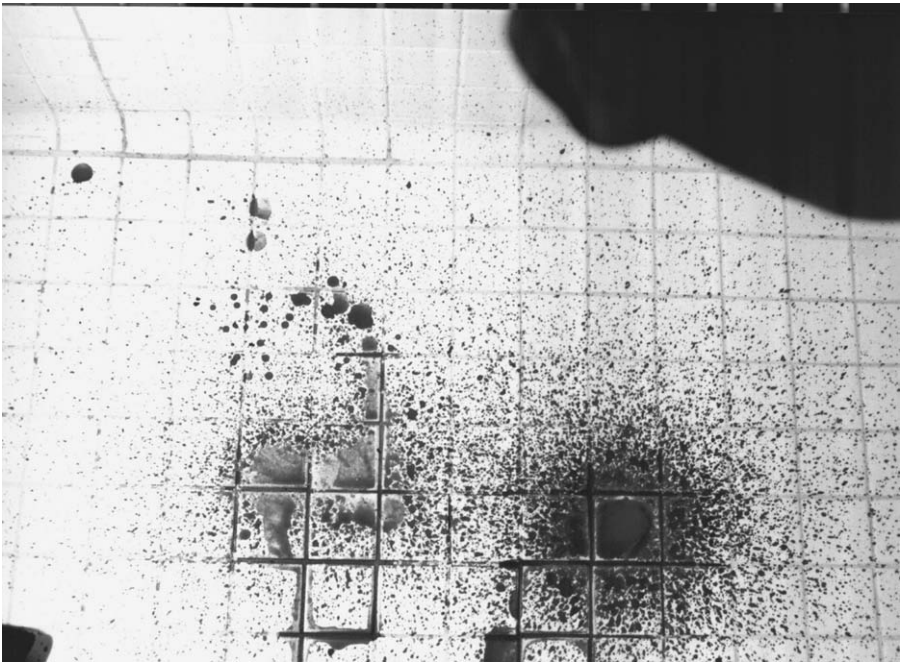

Figure 3.18 A more developed drip pattern. The number of small spatter stains projected out from the primary stain are in the thousands.

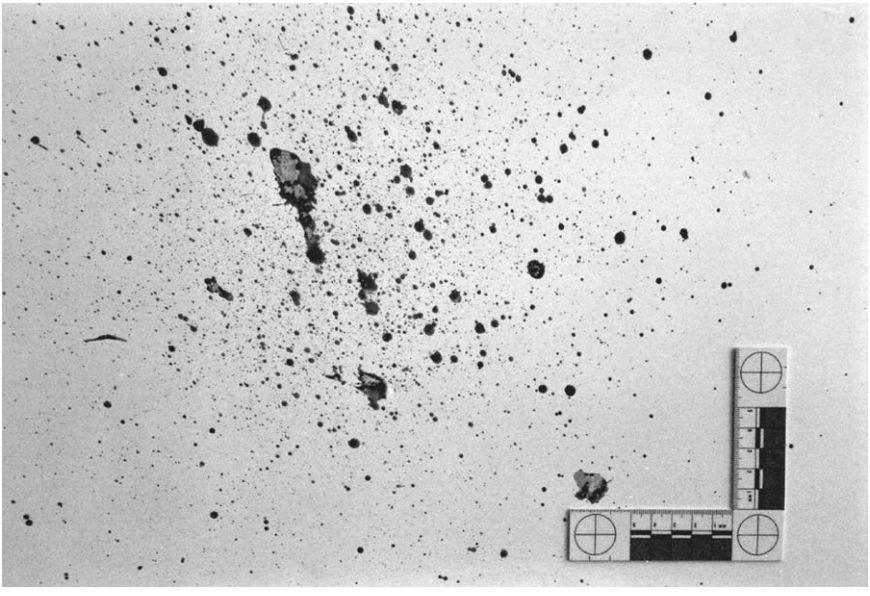

Figure 3.19 Expirated blood. Blood forcefully expelled from a nose. The subject was on his hands and knees, with the face about 2 ft above the target. (Photograph courtesy of Tom J. Griffin, Colorado Bureau of Investigation.)

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Figure 3.20 Expirated blood. The pattern resulted from a murder victim collapsing and breathing onto the area where the cloth bag was located.

The ranges of size in expiratory stains can mimic both medium- or high-velocity spatter patterns.

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

Fly Spots

Stains resulting from fly activity (Figure 3.21)

The activity of flies in the crime scene will often create stains that may first appear to be spatter. The flies may either regurgitate, excrete, or track small amounts of blood onto items within the scene, resulting in such stains.

Flight Path

The overall orientation of how a droplet strikes a given target. Flight path is defined by both the impact angle and the directional angle in consideration with the point of origin.

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Figure 3.21 A fly spot pattern. Fly spot stains found on a bathroom mirror bracket 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. Note the tail associated with the upper stain. Tails and other structures created by the movement of flies in and around the deposit may be mistaken for spatter and satellite stains. (Photograph courtesy of Det. Mike McGuffey, Covington Police Department, Kentucky.)

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 point of origin, impact site, target, or origin. All seem related, but used in specific contexts they have distinct definitions and 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

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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 drop's impact point, 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 which "impact site" you are referring to.

Origin/Point of Origin/Area of Origin

The point or area in three-dimensional space where a blood drop originated

It might seem that the terms origin and impact site go hand in hand, but origin and impact point are distinct concepts. In most instances, the impact site is the origin of any given stain or spatter. One particular example of when this is not true is a cast-off stain. A weapon coming in contact with a body creates an impact site and thus a source for blood. This blood is transferred to the weapon and, as previously discussed, is carried with the weapon as it is swung. At various points along the arc of this swing, blood may be cast off and impact some target surface. In tracing the origin of these stains, using principles to be discussed later on, the point of origin will identify that area in space where the drop detached from the weapon. Rarely, if ever, can it be defined as a precise xyz point in space. Point of origin, then, refers to the general area where the drop originates in regard to its flight path.

Parent Stain

The main stain from which satellite spatter originates (Figure 3.22)

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

When a drop impacts a target, surface tension, molecular attraction, inertia, and velocity all act in their own ways 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" and the smaller stains are the "satellites." A parent may spawn multiple satellite stains, but a satellite has only one parent stain (Figure 3.23). 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.

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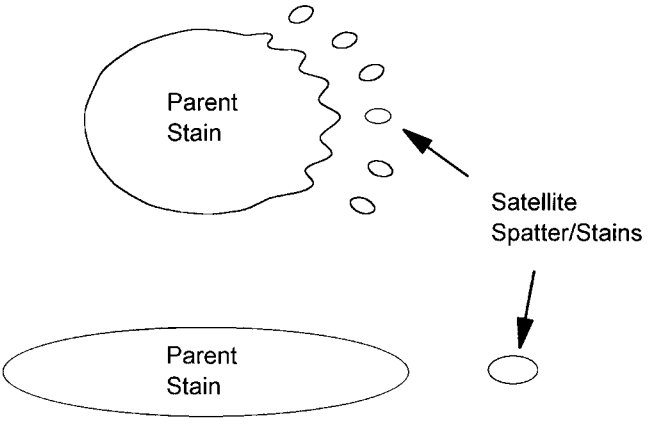

Figure 3.22 Identifying parent from satellite. The major portion of the stain resulting from a droplet's impact is the "parent stain." Small droplets often detach during impact, creating smaller stains referred to as "satellite stains."

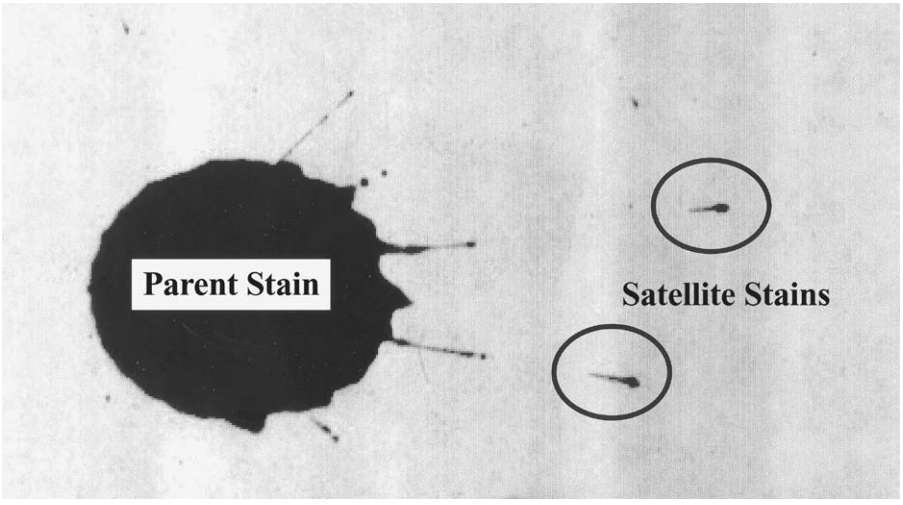

Figure 3.23 A parent stain with five attached or semi-attached satellite stains and two detached satellite stains. Note that the tail of a detached satellite points in the opposite direction of tails and spines associated with the parent stain.

Projected Blood

Blood that impacts a target or surface under pressure and in volume

The most obvious incidence of a projected bloodstain is the arterial spurt or gush.

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Ricochet Stain

Blood that impacts a secondary 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 distinctly false conclusions.

On impact, the drop shows the directionality evident as it struck the target. We should always examine individual stains with some consideration for the possibility of a ricochet. Because directionality is the easiest information to glean from a given bloodstain, it is also often taken for granted.

Satellite Spatter

Small stains created when droplets detach from a parent drop as it impacts a target (see Figures 3.22 and 3.23)

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 (as in the case of the "wave cast-off stain";[7] Figure 3.24) or many (as in the case of a drip pattern), 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 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 match parent to satellite.

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, 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 subsequently moved

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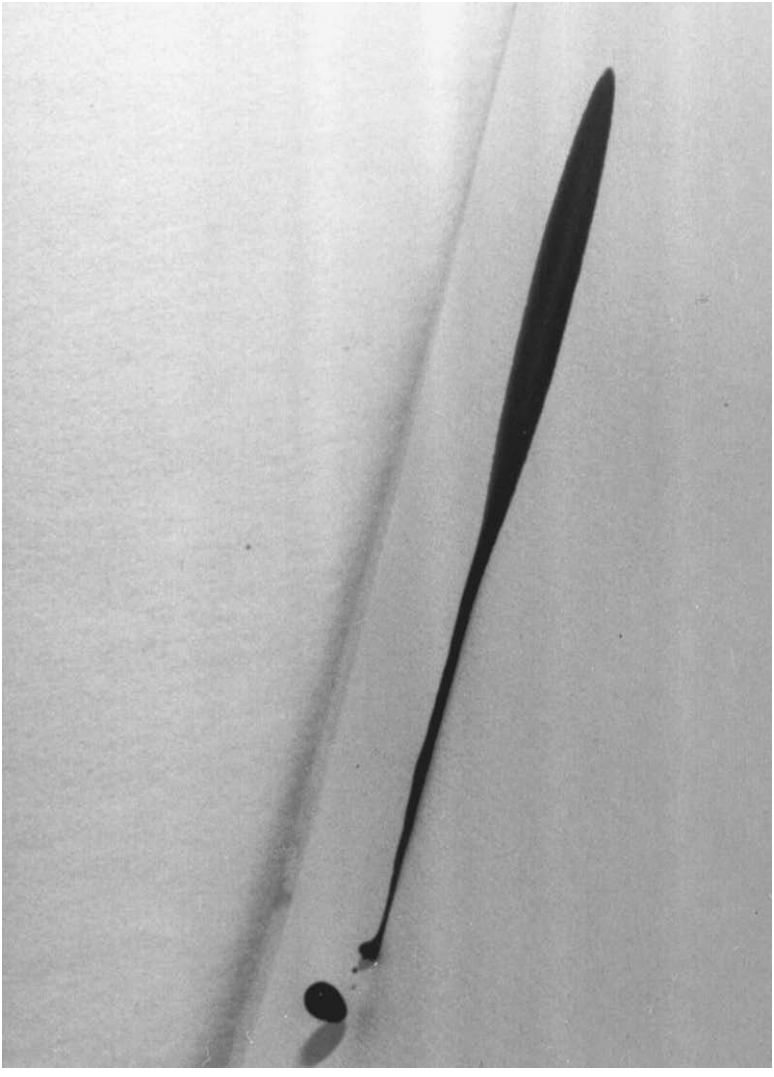

Figure 3.24 The action referred to as "wave cast-off." As the mass of blood is displaced in an impact a small droplet or several droplets may form on the leading edge. These drops are projected away from the main stain. This photo captures a primary satellite droplet that has formed and is still in flight.

from its original position, the remaining target may exhibit some aspect of the 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 and shadowing are used to describe a pattern of this nature, because the voided area casts a "shadow" of the object onto the target.

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Figure 3.25 A void pattern. While the victim was seated on the couch, a significant blood flow occurred on both sides of her body. After the victim collapsed from the couch, the area that had been protected by the body was 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. In the example of Figure 3.25, it is evident the victim was at one point seated on the couch while a significant blood flow occurred. This type of information helps us place victims in very specific positions at discrete moments in time.

Skeletonized Stain/Skeletonization

A bloodstain that, although disturbed, still reflects its original shape and size (Figures 3.26 and 3.27)

Once deposited, blood will usually begin drying from the outer perimeter inward toward the center of the stain. If the stain is disturbed prior to completion of the drying process, the resulting effect is referred to as skeletonization. In this

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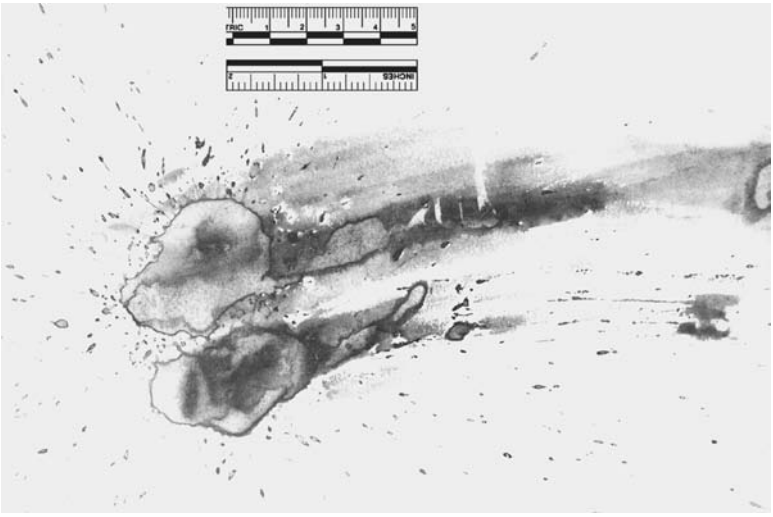

Figure 3.26 Evidence of skeletonization in a wipe pattern. The ring surrounding the wiped bloodstain is referred to as skeletonization and indicates a period of time passed between the deposit of blood and the wiping action.

effect, those portions of the stain that have dried remain undisturbed, whereas the wet blood is either wiped away or smeared.

Skeletonization not only helps us recognize the original size and shape of the stain, 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.

Spines

Linear characteristics evident in both single-drop stains and volume stains (Figure 3.28)

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 not only in 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 3.29). Spines often result in this instance. The length of the spines themselves depends on the quantity of blood present in the stain and the nature of the force applied.

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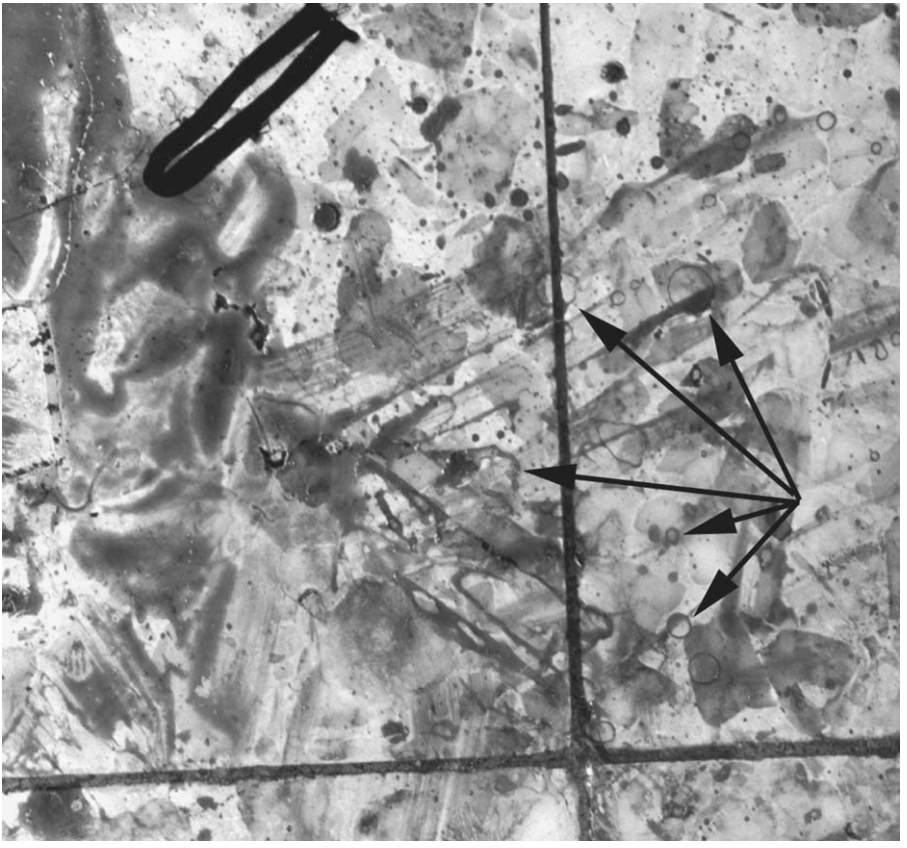

Figure 3.27 Multiple stains showing minor skeletonization intermixed in a wipe and partial palm print. The stains were disturbed by the movement of fingers and a hand through them. The individual claiming to have found the bodies some hours after their deaths stated he became bloody while checking the 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. Clearly, the stains were disturbed soon after they were deposited. (Photograph courtesy of Claire Dawnson-Brown, Travis County District Attorney's Office, Texas.)

Splash

> **The stain pattern created when a volume of blood impacts a target with minimal force; such a stain tends to have a consolidated appearance** (Figure 3.30)

Splashes of blood are relatively uncommon at the crime scene. If splashes are present one must consider the possibility of a staged scene, because the mechanism to create a splash is generally inconsistent with the events

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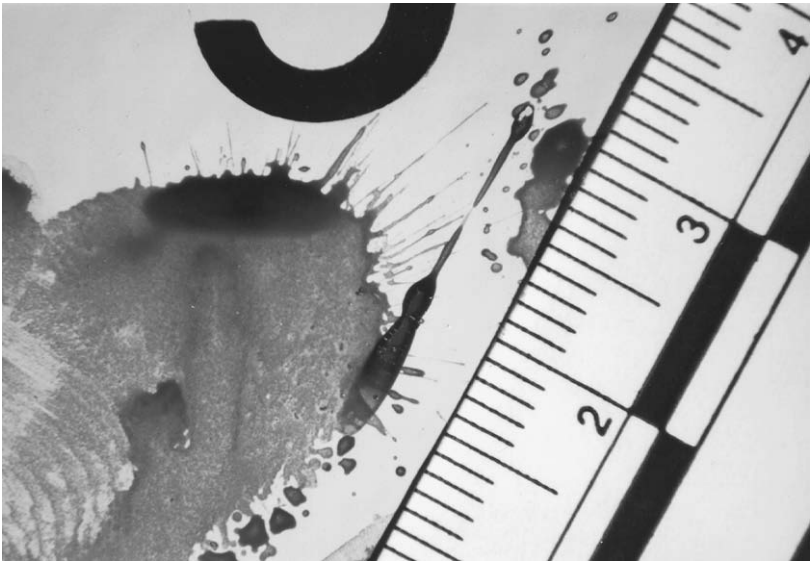

Figure 3.28 Spines occur even in instances of small volumes of blood. Note the linear features at the tip of the finger pattern transfer.

Figure 3.29 A boot stomp in blood. Note the numerous spines present in the stain. As a general rule, the presence of spines in a stain indicates that some level of force was involved in the stain's creation.

associated with most violent crimes. Nonetheless, splashes sometimes do occur in homicide scenes, as shown in Figure 3.31. A more typical example of a naturally occurring splash may be found in a suicide, where the victim shoots himself in the head while sitting or standing. A quantity of blood

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Figure 3.30 A splash pattern. This splash pattern was produced in a laboratory setting by tossing a small volume of blood against the target. Splash patterns tend to have a cohesive look, with little breakup of the blood into smaller stains.

can pool in the remnants of the lower skull and be thrown out when the body collapses, causing the splash.

Passive Flow

A blood flow created by gravity alone, with no circulatory action involved

A common form of stain found at many scenes is the flow pattern. These patterns are found on the victim, on objects in the scene, or on surfaces in the scene. Only the wound or body position can prevent gravity from creating passive blood flows. Depending on the manner in which the body is moved and positioned, passive flows resulting from gravity may be extensive.

Pattern Transfer

Any stain created when a wet bloody object comes in contact with another surface

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Figure 3.31 A splash pattern associated with a homicide scene. (Photograph courtesy of David Stiles, Texarkana Police Department, Arkansas.)

Pattern transfers are very likely 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 blood contaminates an object, it is difficult to clean up and will tend to contaminate (or stain) anything the first object subsequently comes in contact with. Figure 3.32 shows a pattern transfer caused by a hand, Figure 3.33 shows a pattern caused by a butcher knife on a carpet, and Figure 3.34 shows a pattern created by a pair of scissors.

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

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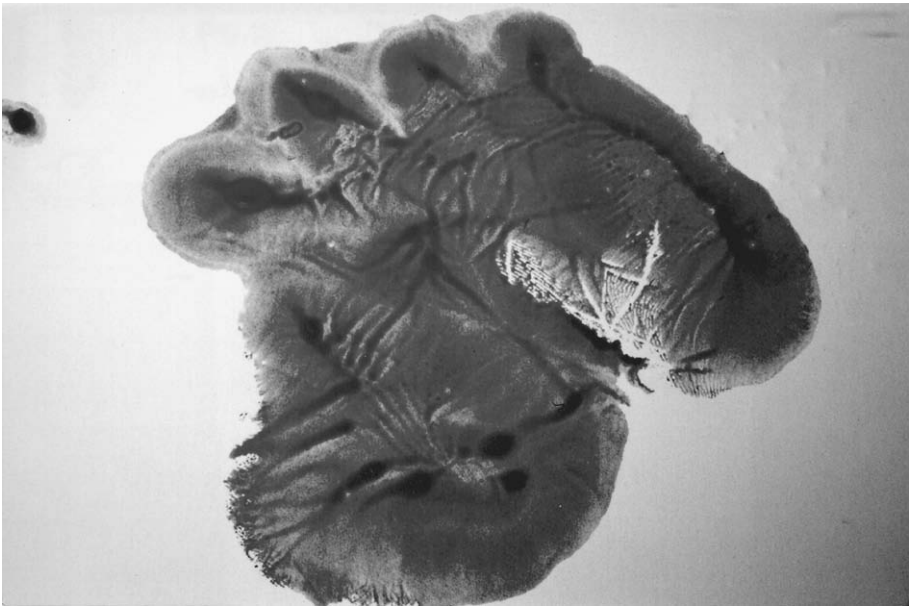

Figure 3.32 A pattern transfer that exhibits evidence of capillary action. Within the pattern, however, is sufficient detail to point to a friction-ridged surface as the pattern's source. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

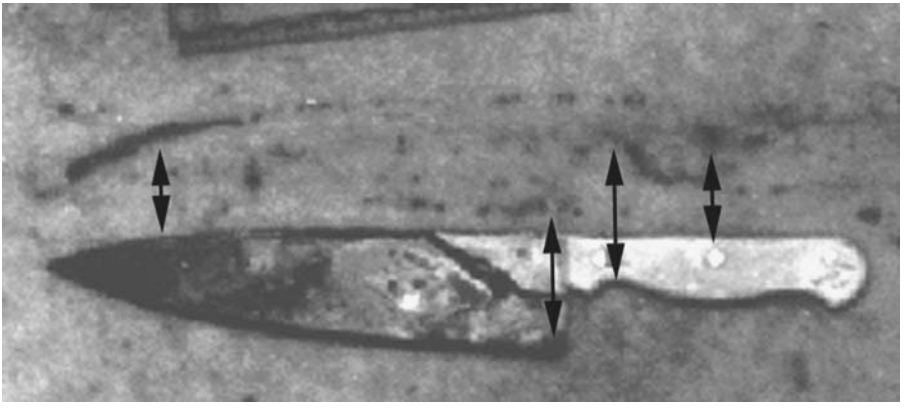

Figure 3.33 A pattern transfer on a carpet associated with a bloody butcher knife. The knife was placed adjacent to the pattern transfer — after collection of samples and forensic evaluation of both items of evidence — in order to show consistency between the pattern and the weapon. Note the heavy flow along the top edge of the blade toward the tip and the matching saturated area of the pattern transfer.

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Figure 3.34 A pattern transfer that exhibits distinct linear features. The pattern's source was a bloodied pair of scissors. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

bludgeon) is cleaned, and stains caused by the weave or pattern present in bloodied clothing or bedding.

Wipes and swipes may exhibit characteristics of the item causing them and as such also qualify as pattern transfers. 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.

Saturation Stain

An irregular stain caused by contact with a significant blood source (e.g., pooled blood or a blood flow) (Figures 3.35 and 3.36)

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Figure 3.35 A large saturation stain on bedclothes. These irregular stains usually mar other patterns of interest.

Figure 3.36 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 placing the victim when the saturation occurred. The source for the saturation was a large blood pool on the floor. Thus the victim was most likely oriented feet down (e.g., kneeling) when the saturation occurred.

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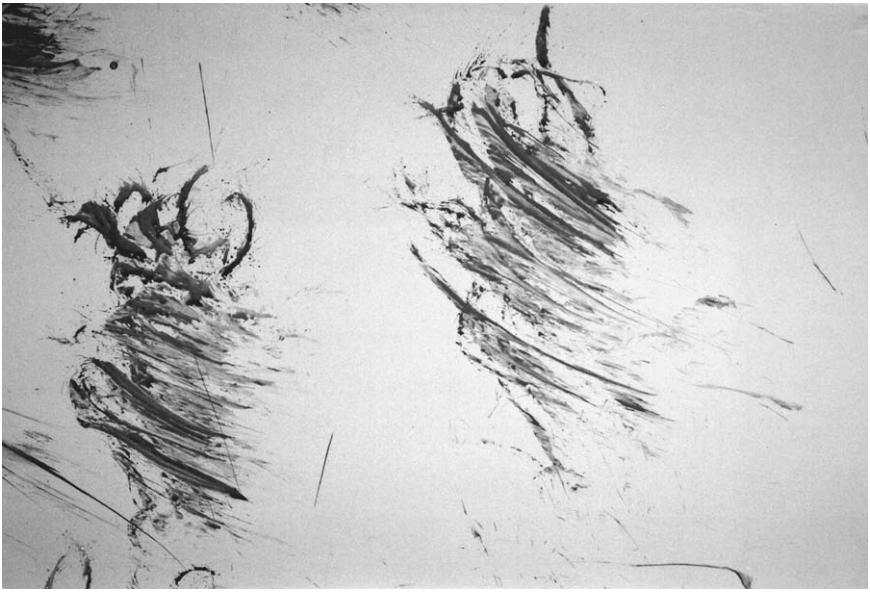

Figure 3.37 A classic swipe pattern created by bloody hair. Note that the motion of the hair (i.e., left to right) is evident by examining the feathering of the pattern. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

Saturation stains, more often than not, 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. This often results 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.

Swipe

> **The transfer of blood onto a target by a moving object that is bloodstained; the motion involved is generally considered as some type of lateral movement** (Figure 3.37)

Wipe

> **Stain created when an object moves through a preexisting bloodstain on another surface; the motion is assumed to be a lateral movement**

Figure 3.38 shows a wipe caused by the sliding motion of a foot. Figure 3.39 is a wipe caused by a shoe. The function of a wipe or swipe in analysis is

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Figure 3.38 A wipe pattern created by the victim's feet moving in a preexisting blood pool.

Figure 3.39 A wipe pattern. Evident in the lower right-hand section of the photograph is a wipe coming out of the smaller pool of blood.

usually one of sequencing. The first consideration is to distinguish what was bloodied by what (defining the stain as a wipe or swipe). 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.

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Figure 3.40 A spatter pattern consistent with the medium-velocity impact spatter definition. This spatter resulted from a blow to the face with a baseball bat.

Velocity Impact Patterns

Depending on the analyst's background, the three velocity impact pattern definitions can be considered as anything from the Holy Grail to pure heresy. It is important to understand these three terms, because they are often used and abused. In discussing spatter and stains, one will hear the terms *low velocity*, *medium velocity*, and *high velocity*. Before considering these definitions, remember that the size range discussed is for the majority of spatter or stains present; in other words, the preponderant stain size. Rarely are there singularly sized stain patterns. In any pattern we will normally see varying sizes of spatter present.

Low-Velocity Stains

Low velocity is considered to be a force or energy equivalent to normal gravitational pull up to a force or energy of 5 ft/s. The resulting stain is relatively large, usually greater than or equal to 4 mm in diameter.

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Figure 3.41 Spatter on a telephone receiver consistent with the high-velocity impact spatter definition. (Photograph courtesy of Iris Dalley, OSBI, Oklahoma.)

Medium-Velocity Impact Spatter

Medium-velocity impact spatter (MVIS) is usually considered to be a pattern of spatter in which the preponderant stain size ranges between 1 and 4 mm in diameter (Figure 3.40). The force or energy for creation of the stain is said to be between 5 and 25 ft/s.

High-Velocity Impact Spatter

High-velocity impact spatter (HVIS) is usually considered to be a pattern of spatter in which the preponderant stain size is 1 mm or smaller in diameter (Figure 3.41). The force or energy for creation of the stain is said to be 100 ft/s or higher.

There is an obvious consideration in using these terms. Are the demarcation points for the force scientifically valid? The issues surrounding velocity labels have plagued the discipline for years. However you view this issue, in discussing velocity labels, always be cautious. Velocity pattern definitions are discussed in greater detail in Chapter 7.

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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 contention 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.

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 whatever message is sent 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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Understanding the Medium of Blood

4

What is blood? What are its physical properties and how do they affect the resulting shapes of stains observed by the analyst? Must the analyst understand fluid dynamics and serology to properly conduct analysis?

The answer to the last question is a resounding NO. Yet understanding the properties of blood has a function for the bloodstain pattern analyst. In this chapter we will attempt to describe in layman's terms the medium of blood and how it reacts with its environment.

General Properties of Blood

Blood is a complex fluid that makes up approximately 8% of the total body weight of humans. As a rule, this equates to 5 to 6 l (liters) for males and 4 to 5 l for females.[1] Blood viscosity usually ranges between 4.4 and 4.7. Viscosity by definition is resistance to flow. Fluid viscosity is compared against water, which is considered to have a viscosity of 1. Blood, then, is more resistant to flow than water. Viscosity in blood is primarily the result of the hematocrit (the proportion of cellular material to fluid). Wider variances of blood viscosity are possible; however, whether distinctly higher or lower, such a variance would represent a major medical condition in the individual involved.[2] For this reason we can be relatively sure that the viscosity found in generally healthy humans, certainly for those up and walking about in a crime scene, remains somewhere within the 4 to 5 range. The issue of viscosity has a direct effect on the damping of oscillations in blood droplets, which we will discuss in greater detail later in this chapter.

Blood has an adhesive quality, easily observed by laymen and noted by medical professionals.[3] This stickiness is of particular interest to the analyst,

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because this quality results in a variety of pattern transfers in the crime scene. A little blood can go a long way in contaminating everything with which it comes into contact.

The circulatory system serves many functions in the body. Obviously, a primary function is to provide the body with oxygen and nutrients while removing waste. Another function of particular concern to the analyst is protection against blood loss. The cardiovascular system is a closed system and breaching represents a major threat to survival. Therefore, our bodies act through various mechanisms to reduce blood loss, thereby increasing overall survival chances.

Blood Make-Up

As a medium, blood is broken into two components: plasma and the formed elements. The plasma makes up 55% of blood, whereas the formed elements make up 45%.[4]

Plasma, the fluid component of blood, is broken down into four general components — water, soluble proteins, organic acids, and salts. By volume, plasma is 91% water, 8% protein, 1% organic acids, and 1% salts. The proteins include fibrinogen, which plays an important role in clotting.[5]

The formed elements are the true cellular material of blood. There are three basic types of blood cells: erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (platelets). All three types develop from a single cell, the hemocytoblast; however, in its transformation each cell takes on properties that are of some interest to the analyst.[6]

Red blood cells represent the majority of the formed elements. There are about 4.8 to 5.4 million cells per cubic millimeter of blood.[7] Red blood cells have two properties of particular interest. The first is the presence of hemoglobin within the cell. Hemoglobin is a red pigment that gives blood its color and, hence, red blood cells their name. As the oxygen content increases in the blood, so does the bright red pigment of the hemoglobin. The second property of interest is the absence of a nucleus in the red blood cell. In the process of maturing from a hemocytoblast, the red blood cell sheds the remaining cell material including the nucleus.

The analyst must consider that because the red blood cells present in the stain have no nuclei, they serve no function in current DNA analysis. In fact, when considering blood by total volume, about 99% contains no material of use to DNA analysis. The remaining 1%, which is of value, is randomly distributed throughout the total blood volume. Therefore, we should not be too surprised by inconclusive results. This knowledge does not preclude us from submitting all stains found at the scene. Remember, it is a random

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process that determines what proportions of cells are found in the stains. Also, as DNA procedures evolve [e.g., PCR (polymerase chain reaction) and STR (short tandem repeat) testing] we see better results from smaller samples.

White blood cells can be broken down into five subcategories. In general, they all act to fight infections and destroy old cellular material and other invading microbes. White blood cells make up less than 1% of the total formed elements, which equates to about 5000 to 9000 cells per cubic millimeter.[8] They have nuclei and are the only material present in the blood for which DNA analysis is currently possible. Again, the random distribution or subsequent degradation of the sample may leave a serologist with little if anything with which to work.

The third type of blood cell is the platelet. Platelets, like red blood cells, also lack a nucleus. Although occurring in larger numbers than the white blood cells, there are substantially fewer platelets than red blood cells. Generally, there are about 250,000 to 400,000 platelets per cubic millimeter of blood. The platelet serves a single function: to help in the chain reaction of the clotting mechanism and thereby reduce blood loss. Platelets have irregular shapes and are quite small under normal conditions. They change drastically, however, when they encounter elements present in damaged blood vessels (e.g., collagen). Upon encountering a damaged vessel, the platelets increase in size and their shapes become even more irregular. At the same time, they become sticky and begin to adhere to surrounding fibers in the vessel wall. The resulting accumulation of platelets is known as a "platelet plug." In smaller vessels the plug, by itself, can effectively control blood loss.[9]

The Body's Response to Breaching of the Circulatory System

When breaching of the circulatory system occurs, the body reacts in three ways to control the blood loss. The first mechanism is the vascular spasm. Simply put, smooth muscles in the vessel wall contract to decrease the size of the vessel, thereby reducing the flow of blood through it. This mechanism is said to reduce blood loss for up to 30 min following injury, allowing time for the other blood loss mechanisms to engage.[10]

The second mechanism is the platelet plug. As discussed, platelets change their shape when they encounter damaged blood vessels. They are able to plug holes in the circulatory system, reducing if not stopping blood loss.

Coagulation or clotting is the third process. Present in blood are 13 different clotting factors. These factors can initiate clotting either intrinsically (i.e., from within the blood itself) or extrinsically, which is based on trauma to surrounding tissue. Whichever the case, the process occurs in three steps.

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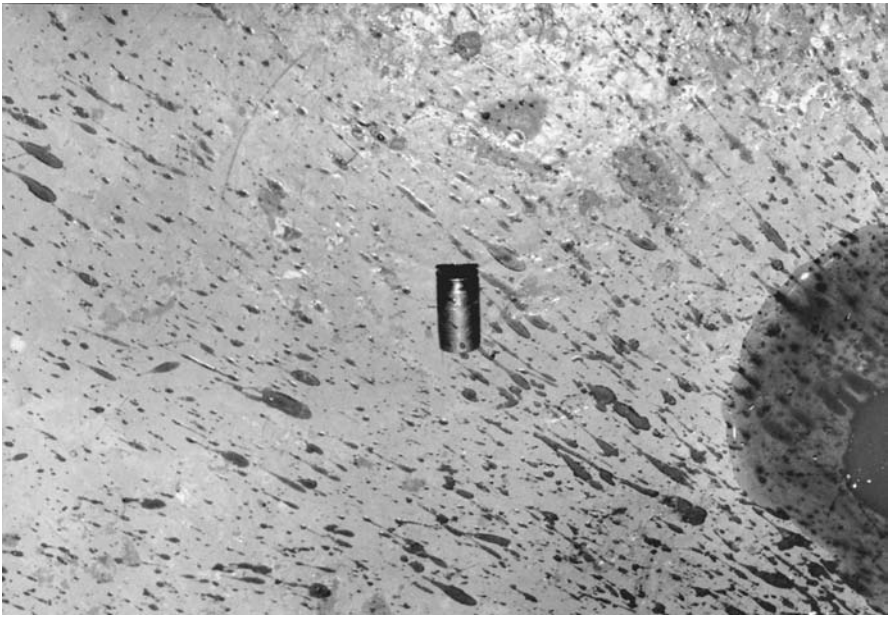

Figure 4.1 Serum separation. The puddle located in the lower right-hand portion of the photograph exhibits separation of the formed elements from the serum.

The extrinsic pathway is shorter and occurs almost immediately after trauma is sustained. In the first step of the extrinsic pathway, the damaged tissues release substances that create what is known as a prothrombin activator. The first step of the intrinsic pathway takes longer, usually at least several minutes. The blood in contact with collagen begins a series of events involving the various clotting factors, which ultimately releases this same prothrombin activator.

The second and third steps of both pathways are the same. The prothrombin activator, in the presence of calcium ions in the blood, converts prothrombin into thrombin. The thrombin in the presence of calcium ions converts soluble fibrinogen into insoluble fibrin. Thrombin accelerates the production of the prothrombin activator, which produces more thrombin, which in turn produces more prothrombin activator, and so on.[11] Once set in motion the process builds momentum on its own.

The clotting we observe at crime scenes gives us a glimpse at the result of this overall process. The fibrin takes on a very structured form, capturing within it the blood cells. As with blood left to clot at the scene, one sees only the serum (typically a clear, straw-colored liquid) that surrounds the clotted mass (the fibrin fibers and blood cells) (Figure 4.1).

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Circulatory System Considerations

At any given moment the 4 to 6 l of blood present in the circulatory system is distributed as follows:

58% in veins, venules, and venous sinuses
13% in arteries
12% in the pulmonary vessels
9% in the heart
8% in the arterioles and capillaries[12]

Although not always of immediate interest to the analyst, understanding this blood reservoir concept may at times help explain the presence of a large volume of blood at a scene. For instance, lacking evidence of active bleeding, but finding a distinct injury to the heart, one should not be surprised to find 20% of the body's total volume of blood present in a passive flow. Nor should we be surprised that it all occurred as a result of a passive flow. The heart and major pulmonary veins easily hold this volume. On occasion the analyst may need to consider these reservoir amounts, correlating specific injuries sustained to the amount of blood present at the scene. This consideration may assist the analyst in differentiating blood lost from active bleeding and that resulting from passive flow following death.

Reaction of Liquid Blood to Force

A fluid is defined as a substance that cannot maintain its own shape, but takes the shape of its container.[13] 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 and is the basis of hydraulics. Blood is no less affected. The displacement of blood by some force, such as a hammer, results in spatter. Figures 4.2 and 4.3 demonstrate the displacement of a blood mass. The photos are from the video production, "Blood in Slow Motion," created by the Metropolitan Police Forensic Science Laboratory. The still photographs capture the blood as it is being struck and actively displaced. In Figure 4.2 a structure of blood is evident to the lower right of the hammer and blood mass. This mass of blood is being projected outward and is in flight. In Figure 4.3 this mass is expanding and beginning to break up. As the force overcomes the viscosity and surface tension of the displaced mass/structure, it will degenerate into small individual blood droplets. Figure 4.4 is a close-up photograph of blood being ejected from a mouse-trap device.

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Figure 4.2 As a mass of blood is struck by an object, 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.)

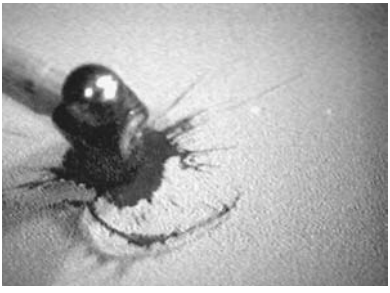

Figure 4.3 In this photograph, the blood ejected to the top right of the hammer head is continuing to break apart and ultimately will become primarily spatter. (Photograph courtesy of the Metropolitan Police Forensic Science Laboratory, London, England.)

Note the spindly structures moving out away from the source, which was situated to the left of the photo. Also note that numerous droplets have already formed at this moment. One point for consideration is that one can never predict accurately and fully where spatter will or will not be ejected to. In Figure 4.3, spatter is ejecting primarily to the right of the head of the hammer. The manner of contact and the paths available for the blood to displace will define the resulting spatter dispersion.

Droplet Dynamics in Flight

Hopefully, the reader now better understands blood, or at least its behavior in the circulatory system. More to the interest of the analyst is how blood reacts once shed. In flight, what characteristics does it have?

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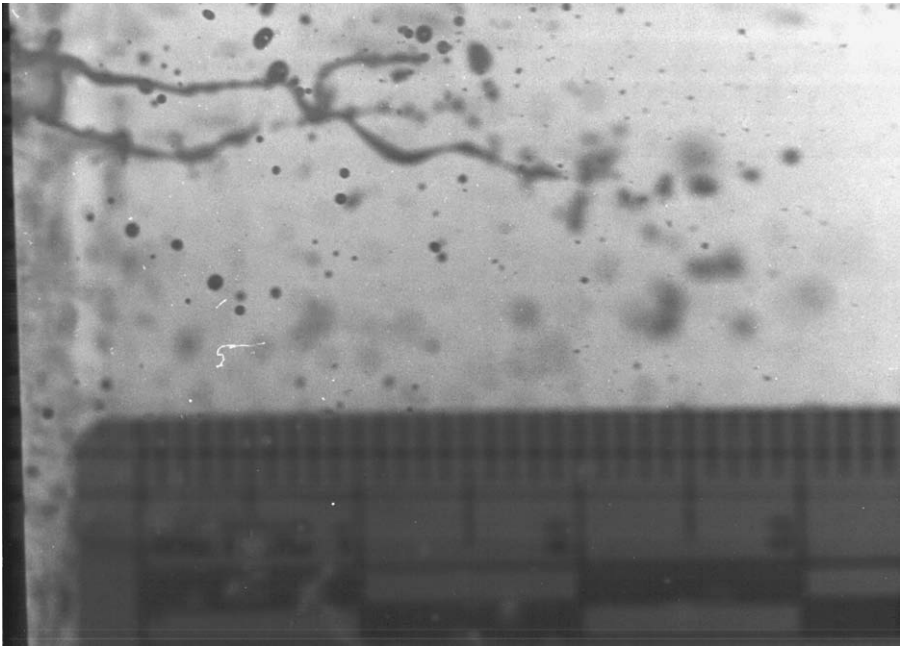

Figure 4.4 Another example of blood displacement due to a force. A mousetrap device to the immediate left of the photograph displaced the blood. As it displaces, both spine-like structures and droplets are still evident. The spines will degenerate into droplets when the force of displacement overcomes the surface tension and viscosity of the liquid blood in the spine.

Much has been written about the so-called "normal drop" of blood. It should not be surprising that our first consideration is the droplet itself. What shape does a droplet of blood attain while in flight? James E. McDonald, in discussing raindrop shapes and answering why a droplet is spherical, said: "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."[14]

Figures 4.5 through 4.7 demonstrate liquid blood forming on the tip of a screwdriver and the subsequent detachment of a single drop. As evident in Figure 4.6, the forming droplet, while still attached to the mass of blood on the screwdriver, takes the shape of a teardrop. Once fully detached this shape becomes a sphere. The droplet is not, however, a perfect sphere, because the droplet is obviously oscillating in Figure 4.7. In considering how internal pressures present in droplets impacted on the force of surface tension, McDonald found that small droplets (≤1 mm in diameter) were almost perfect spheres. Larger drops, however, were unable to maintain the perfect sphere shape in flight and often resembled nothing less than a "hamburger bun."[15]

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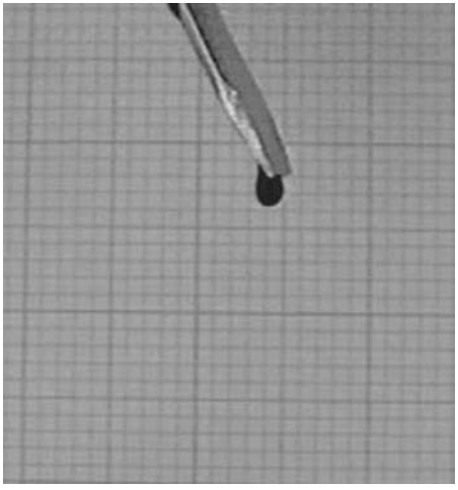

Figure 4.5 A droplet of blood forms on the tip of a screwdriver. Surface tension of the liquid holds this mass intact. At the same time the force of gravity is acting on the mass as it forms, pulling it away from the screwdriver tip in opposition to the surface tension.

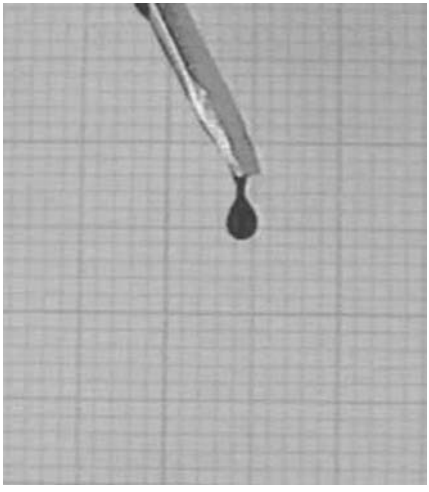

Figure 4.6 At this point the weight of the liquid droplet at the tip has almost overcome the ability of surface tension to hold it intact with the fluid running down the screwdriver. The droplet takes on a "teardrop" shape as it stretches down and away from the tip. Although incorrect, this shape is often associated with blood drops and raindrops in flight. The structure connecting the mass and the fluid on the screwdriver is nothing more than a thin spine of fluid blood.

Dr. Alfred Carter also commented on the issue of shape and surface tension, stating: "With regard to the spherical shape of liquid droplets, it can be explained entirely by the surface tension of the liquid."[16] Although surface

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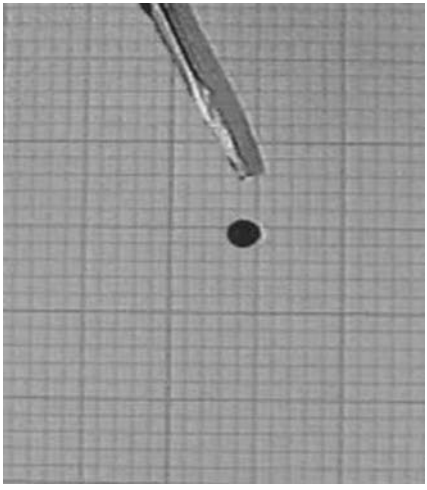

Figure 4.7 The weight of the droplet has overcome the force of surface tension in the connecting spine structure and the droplet is now detached. Once in free flight the droplet is generally spherical, although it is oscillating.

tension acts to shape a droplet into a sphere, it is not the only factor. 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.[17] Thus, if surface tension alone were the force in effect, we might well expect blood droplets to oscillate considerably. In fact they do not, because of their viscosity. To understand viscosity's relationship in maintaining this sphere, we must first consider the force that disrupts this spherical tendency.

In seeking to explain the diverse shapes of raindrops evident in nature, researchers identified the primary force behind them as oscillations present in the mass of the droplet. As McDonald noted in his larger drops, oscillations were evident to the extent he could physically observe and photograph them. Such oscillations occur naturally in raindrops, particularly those with larger diameters. They result from various forces including, but not limited to, collisions with other droplets.[18]

Before going further, it is probably best to define these oscillations and their effect on the analysis. (Refer first to Figure 4.8.) 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 sides or top, the shape of the droplet would change to accommodate the liquid volume moved by the pressure. The volume would not change — only the shape.

While in flight, oscillations in droplets have the same effect on the shape, only the force for change comes from within the droplet. The closest analogy

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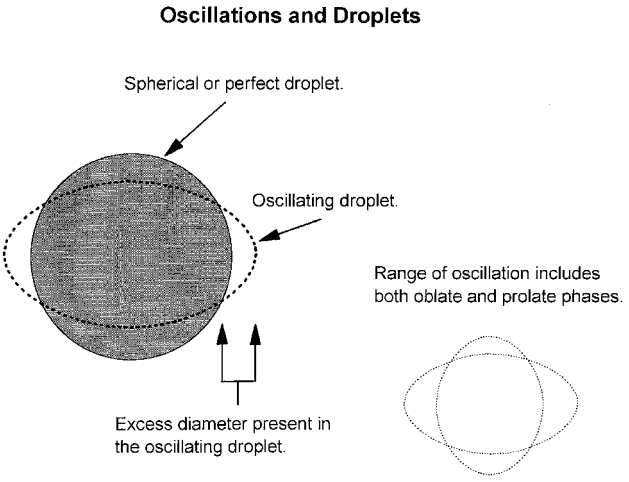

Figure 4.8 Oscillations in droplets. As a result of their formation, droplets oscillate. This causes a shift of the droplet's mass from a perfect sphere to an oblong spheroid. The oscillation is dynamic; that is, it shifts until the oscillation decays completely. As such, the droplet moves through a wide range of shapes as the oscillation shifts back and forth between the oblate and prolate phase.

we can make is that, like a wave, 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 (Figure 4.9). The overall level of this deformation will decrease with time.

With but one major exception, these oscillations have no effect on issues in bloodstain pattern analysis. The exception is in considering impact angle determinations. These angles, in part, are based on the belief that a droplet impacting a surface is in the shape of a sphere. If a blood droplet were to oscillate to any great degree at impact, 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.

For all liquid droplets, size, viscosity, and time affect these oscillations. As analysts we must consider these factors and the resulting range of oscillations present in blood droplets to decide whether our impact angle results are generally accurate.

Ryan, working with water droplets, observed these oscillations and remarked: " … drops smaller than 0.5 mm radius are essentially spherical regardless of surface tension."[19] Regarding drop instability as a factor for breakup, Ryan stated: "Thus, the current experiments lend further credence to the now generally accepted belief that raindrop size is limited by breakup caused by drop interaction rather than breakup from individual drop instability."[20]

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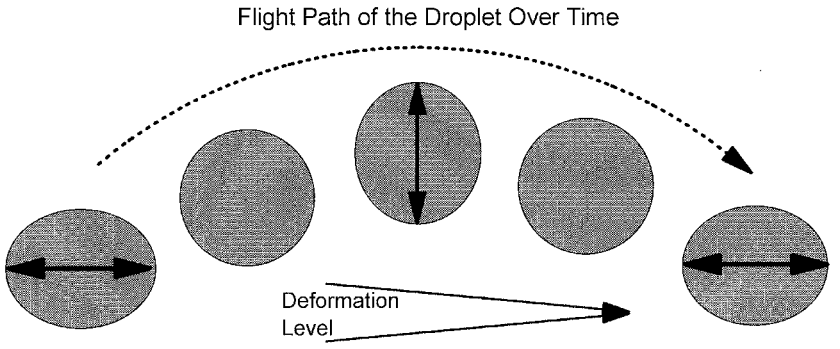

Figure 4.9 Oscillations in droplets move through an entire range of deformations. The most important aspect of the oscillations is that they decay with time. The longer the droplet is in flight, the smaller the remaining oscillation.

Ryan, working with artificially produced drops, created water drops 6 to 9 mm in diameter. He believed, however, a 5-mm-diameter drop would be the largest naturally occurring water droplet. Of particular concern to our issues, he noted that the larger the drop, the greater the level of oscillation.

What size should we expect in the instance of a blood droplet? Pizzola et al. produced low-velocity drops with diameters of about 3.7 mm. They, too, noted that such drops oscillate.[21] MacDonell reported drop diameters up to 4.6 mm.[22] We have observed drops on the order of 5.3 mm, but again these were the result of low-velocity events. Thus, in situations where blood merely forms a drop as a result of gravitational forces (drips and similar actions), we may well expect stable drops with diameters as large as 5 or 5.5 mm. Such drops would have a volume of about 60 µl. This size droplet exhibits distinct levels of oscillations.

We offer a caution in discussing a "standard" or "normal" range for drop size or volume. MacDonell was criticized for alluding to a "normal" drop volume. The primary criticism is that the volume for any drop is determined primarily by the surface area from which it drips. If we do not know the surface, it is difficult to state the volume. Nevertheless, this 5.5-mm-diameter (0.06 ml) size is empirically evident to be the upper limit for a stable blood droplet, whereas MacDonell's 4.6-mm-diameter drop (0.05 ml) is probably more typical of free-falling drops resulting from venous bleeding.[23]

As one might expect, impacts result in significantly smaller drops. While studying impact events, we documented droplets (not the stain) with diam-

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eters ranging between 0.125 and 2 mm. Volumes for such impact droplets are significantly smaller, ranging between 0.008 and 4.18 µl. We are not saying this range is an absolute for all impact events. Just as in the argument against a "standard" blood drop, the size range of droplets in any given impact event would vary depending on the nature of the impact involved. Nevertheless, 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 droplets that create stains 4 to 5 mm in size (medium-velocity spatter) have diameters generally not larger than this 2-mm range.[24] The average diameter of the droplets studied in our effort was 0.6 mm. In 1997, A. A. van Netten and J. M. Dewey, in collaboration with the Royal Canadian Mounted Police, Edmonton Identification Support Section, sought to find a reliable photographic method of documenting spatter as well. 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 reported on droplets created as a result of an impact in a blood pool. The size range evident in the study was 0.26 to 1.45 mm. The average diameter reported, using lamb's blood, was 0.74 mm.[25] The most important point to make here is that when considering impact events we are looking at relatively small droplets that, as Ryan noted, oscillate at a very low level.

As a result of his efforts in raindrop research, Dr. Kenneth Beard reported that raindrop oscillations are related to collisions (analogous to Ryan's droplet interaction) between the larger, faster-falling drops and the smaller drizzle drops.[26] With the issue of collisions and oscillations in mind, we asked Dr. 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.[27]

Dr. Beard provided calculations for defining droplet oscillation that allow us a greater insight into droplet behavior in flight.[28] 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 the damping. Based on this information we know that oscillations in blood droplets damp about four times as quickly as those found in water droplets. We cannot absolutely

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discount these oscillations. At impact they may be quite distinct (up to 40% of the droplet's diameter), but the actual time it takes these oscillations to die out is relatively short.

Raymond, working with pipette-produced droplets, noted oscillations up to 10% of the droplet's diameter.[29] 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.[30] Thus, the high viscosity of a blood droplet helps eliminate oscillations, allowing surface tension to form the drop into a more perfect sphere. Droplets in flight will tend to maintain this spherical shape with few factors present to disrupt them.

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:

- Generally have diameters not greater than 2 mm[31]
- Have oscillations present in the mass of the liquid, but these oscillations damp very quickly
- Are close to being perfect spheres upon impact, which allows a level of confidence for the width and length ratios of the resulting stains

Dr. Beard's belief that collisions among droplets are an uncommon event in blood impacts is also of some interest to the analyst. While studying oscillation damping, we captured photographic images of impact spatter in flight. In these photos the impact droplets were randomly dispersed, with less than 1% colliding in any fashion away from their source. The data sample used in the observation included 70 different impacts and in excess of 600 droplets.[32]

The lack of collisions between droplets in free flight speaks to an important issue. It indicates, as Dr. Beard suggested, that only the impact itself causes breakup in blood droplets. Collisions after creation are too few to cause instability of droplets in flight. Once set in motion, then, droplets do not spontaneously break apart.

Another interesting aspect of droplet behavior is that the droplet's size drastically changes its path in free flight. The effect of air resistance is inversely proportional to the size of the droplet. The larger the droplet, the less the effect and the smaller the droplet, the greater the effect. Thus, given two droplets of differing diameters directed along a path at the same velocity, the larger drop will carry farther than the smaller one. Although projected in a common direction, their respective parabolas will differ. Figure 4.10 is a *TRACKS*® model of several droplets of different volumes.[33] The smallest droplet (Droplet 1), although projected at the same initial speed as the larger drops, quickly loses velocity and falls to the ground.

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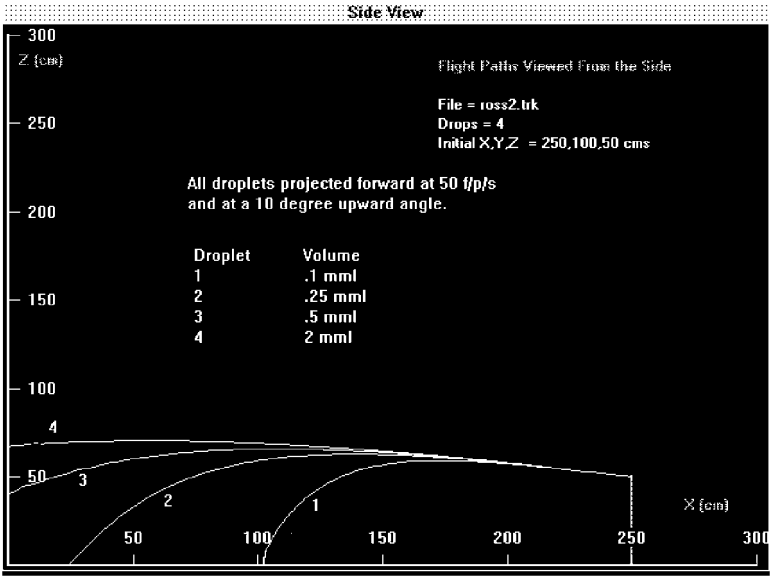

Figure 4.10 Air resistance is inversely proportional to drop size. This TRACKS® model shows several drops projected at the same angle and velocity. The smallest droplet (#1) quickly loses speed and drops to the ground, whereas the larger droplets carry further. This is the effect of air resistance.

This effect is particularly noticeable with very fine droplets such as those associated with gunshot injuries. These droplets carry only a short distance before gravity and air resistance drag them downward. For such small droplets the total distance traveled from the origin will normally not exceed 4 ft.

Droplet Dynamics on Impact

We understand the blood droplet's behavior as it follows a given flight path to its destination, but what happens when the 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 have been 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 the authors, has reported that droplets burst on contact when a rough surface ruptures the droplet's surface.[34-36] This certainly seems logical, but it is incorrect.

One might question why the analyst should worry about what happens during these impacts. After all, analysts concern themselves with the aftermath

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of the impact (the stains), not the impact itself. There are many antagonists of bloodstain pattern analysis. The discipline has been challenged both in and out of court based on a lack of research into blood droplet dynamics. Although only an initial step, the following observations provide a greater understanding of the droplet's dynamic shifts at impact.

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.[37] Some analysts may object to the specific labels we use 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 each of these issues has some effect on the process. The phases, although slightly different, occur in all impacts. The only caveat we make with regard to these observations is that there may be a point of diminished volume in very small droplets at which the later phases are altered. This particular issue requires further study.

In considering our observations, accept them as just that — empirical observations that help us understand the shift and transition the droplet goes through to create a stain. We identify the four phases of impact as follows: 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 they do unnecessarily complicate them. Thus, we will deal with liquid-to-liquid impacts as an aside.

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 well because the blood flows outward, not inward.[38]

The angle of impact affects the contact/collapse phase by defining the nature of the rim and blood flow into it. For example , in a stain impacting at 90°, the blood flow into the rim is equal on all sides. As a result, we see a circular stain with a generally uniform diameter (Figure 4.11).

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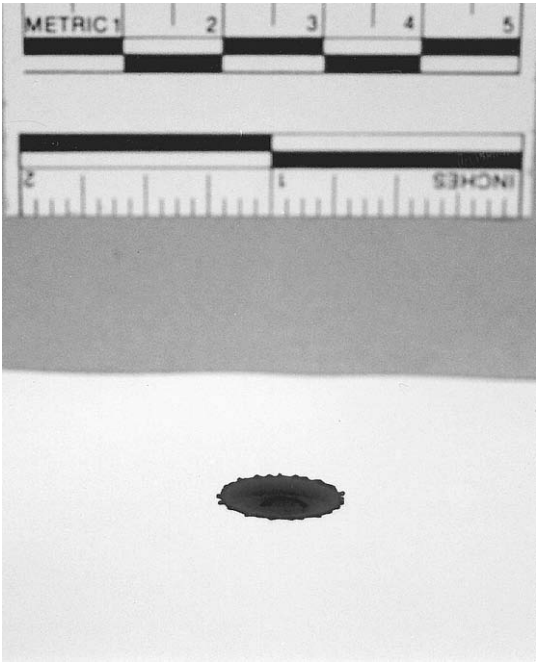

Figure 4.11 A droplet in late contact/collapse phase. A small dimple is barely evident in the center of the developing stain. It is what is left of the still-collapsing droplet.

For droplets impacting at more acute angles, the 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 flows primarily into the area of the rim opposite the direction from which the droplet originated (Figures 4.12 and 4.13). This directional outflow in combination with the droplet's skimming movement during collapse help explain the elliptical shape of the stain.

Surface characteristics have an influence on the contact/collapse phase. Surface irregularities may begin 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.[39] Up to this point there is no apparent disruption of the

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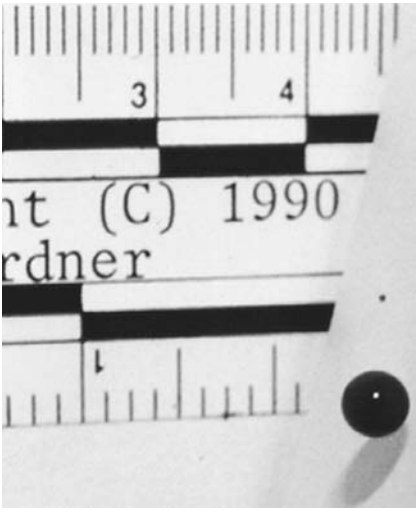

Figure 4.12 Free flight of a droplet just prior to its contact in an acute-angle impact.

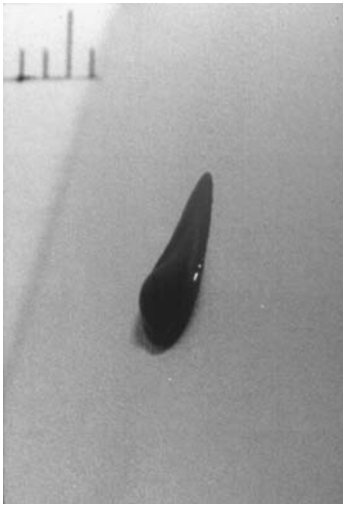

Figure 4.13 Late contact/collapse phase of a droplet impacting at an acute angle. In this photograph about half of the sphere is still intact and evident in the center of the expanding stain. Note that the majority of the blood is being forced into the rim opposite the direction of origin.

surface tension. The droplet, although exposed to considerable shifts in its shape, is still one mass and has not broken apart.

Evident on the boundary rim of the collapsing droplet are dimples or short spines. These appear to form as a result of the blood displacing from the central portion of the stain into the rim (Figure 4.14). The dimples may

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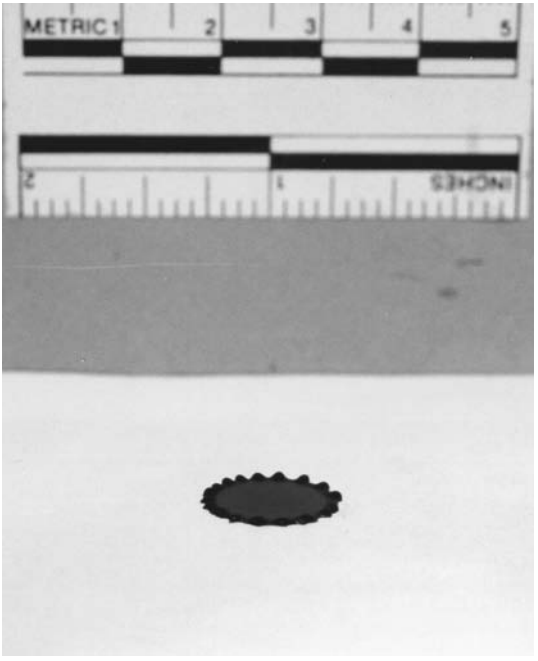

Figure 4.14 Displacement phase in a 90° impact. Note the displacement of the liquid to the rim of the developing stain. All motion up to this point in the collapse is lateral (outward).

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 very evident 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.

Although displacement is only the second phase of the impact, it is interesting to note that the area defined in this phase will also define 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 high as 270% in larger drops (e.g., a 4-mm droplet creates an 11-mm stain). We believe the displacement ratio drops as the volume drops, but this area also requires further study. This ratio may have correlation to the effect of the oscillation evident in the droplet at impact (e.g., a 0.06-mm excess oscillation at impact could result in as high as a 0.16-mm error in the length-to-width ratio).

Impact angle affects the displacement phase only in the nature of the dimples. As was evident in the contact/collapse phase, 90° impacts result in

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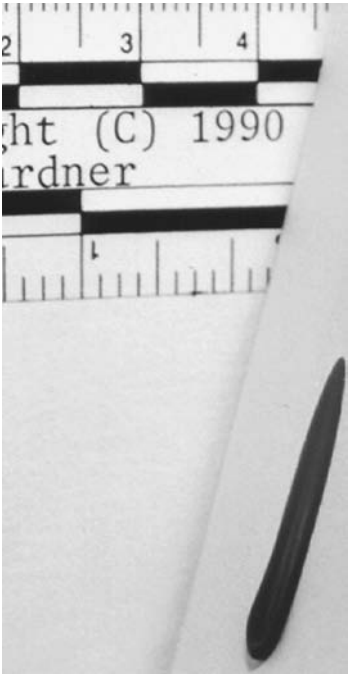

Figure 4.15 Early displacement of a droplet impacting at an acute angle. Note the distinct rim in the leading edge.

development of a symmetrical rim. Thus, in displacement, dimples will also appear symmetrically, surrounding the entire rim. Acute-angle impacts lead to dimples only in the forward edge of the developing rim. A single dimple, as found in a 10 to 20° impact, results in the classic wave cast-off stain. For example, Figure 4.15 exhibits the wave cast-off features during displacement but prior to the development of dimples. Figure 4.16 shows a late displacement phase, in which the dimple is now evident and moving outward. Although often reported, there is no whip or backlash effect evident in the wave cast-off.[40]

Any dimple 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 one of the several dimples that developed in the rim.

The surface texture of the target plays a prominent role in the displacement phase. It is not that a rough target "bursts" the droplet, resulting in the irregularly shaped stains we so often find. In fact, the typical water balloon analogy is severely lacking, because the balloon 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 doesn't burst; it simply shifts its

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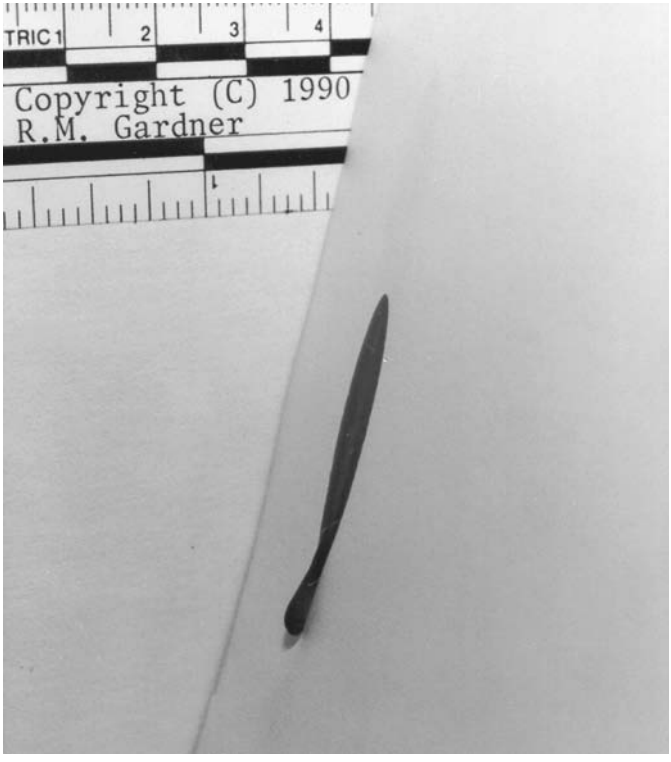

Figure 4.16 Late displacement or early dispersion in an acute-angle impact. The dimple in this photograph is well formed and beginning to show upward movement off the target plane.

shape. As a result of this shifting, on a rough surface the blood flows irregularly into the rim. The volume in one part of the rim may be large, and in another it may be small. The spines that eventually form will also be irregular, because of this difference in volume. This irregular flow will usually result in an abnormal or asymmetrical collapse of the entire structure later in the retraction phase. This eventually results in what analysts would likely call a distorted or excessively spattered stain. Figure 4.17 shows stains created by similar droplets falling the same distance, but to different surfaces. The droplets falling to the rougher surface display distinct distortion. We cannot ignore the effect of the target surface on the collapsing droplet because it may limit subsequent analysis. (Color Figure 1 shows additional examples of the effect of target surface.*)

Droplet velocity also plays a role in the displacement phase. As other authors have indicated, terminal velocity is reached for a given droplet when

* Color Figure 1 follows page 134.

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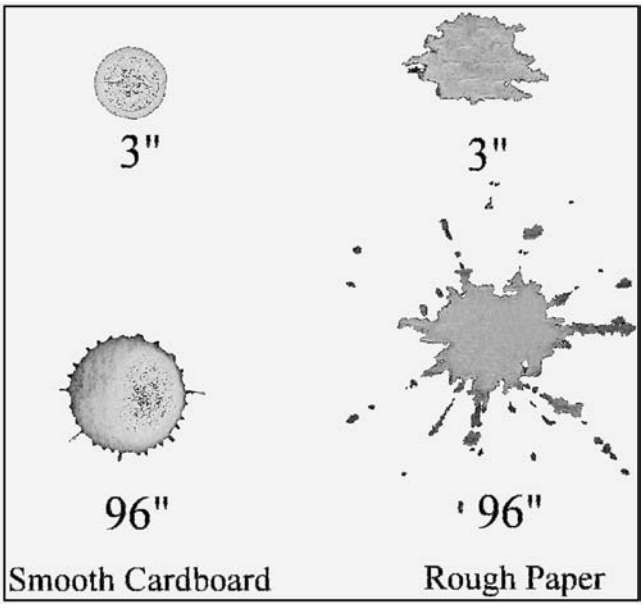

Figure 4.17 Target surface effect. These stains resulted from droplets falling 3 in. and 96 in. onto two different surfaces (rough paper towel and smooth cardboard). Although the droplets do not "burst" on contact with the rough surface, there is an irregular or asymmetrical outflow of liquid as the droplet collapses. This results in irregular-shaped stains. On the smooth surface the collapse is symmetrical, resulting in symmetrical stains.

the effects of gravity are countered by air resistance.[41] This results in a constant velocity.

If we drop similar-volume drops from different heights, the resulting stains will exhibit different overall sizes (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.[42] 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.

In the 1970s, analysts often made a correlation between the size of a stain and the distance with which it fell. They based these conclusions 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 have shown that the volume of a drop varies greatly depending on the nature of the surface on which it forms. 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

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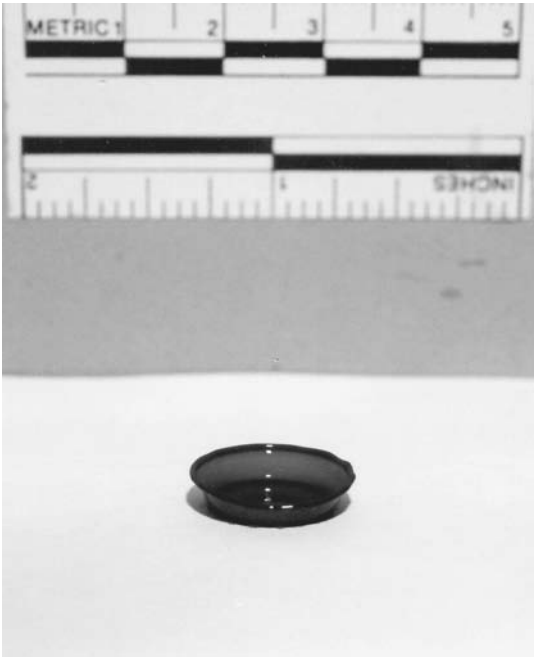

Figure 4.18 Early dispersion in a droplet impacting at 90°. Note the surface tension is still intact although the droplet's mass has shifted dramatically.

in analysis. The only point we can conclude is that increasing the velocity beyond the terminal velocity (as in the case of blood projected by some force) does not cause a greater displacement of the droplet.

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 (Figures 4.18 and 4.19) and the wave cast-off (Figure 4.20).

This phase is easily categorized by the action of the rim. Blood is forced into the rim and dimples, which continue to rise upward and in a direction opposite to the original momentum. 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 dimples rise upward around the entire periphery of the stain (see Figure 4.18). Whereas the liquid's motion in displacement was lateral, in dispersion it is upward and outward.

For droplets impacting at more acute angles, the blossom builds more like a wave on one side of the rim. This wave in turn creates one or more

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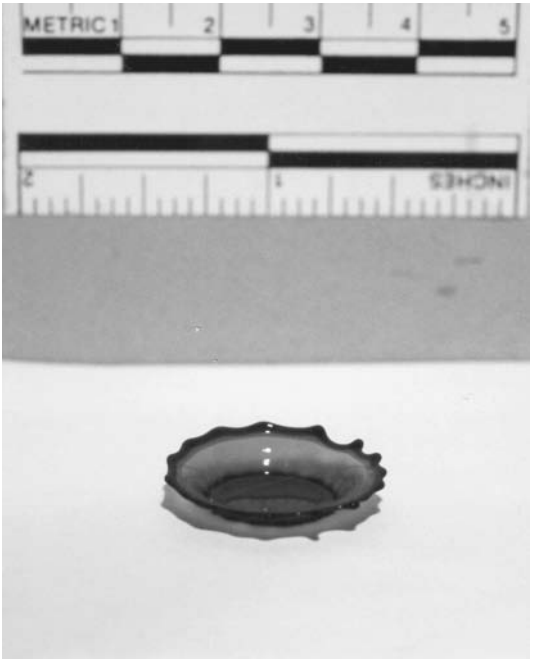

Figure 4.19 Late dispersion. Note the small dimples present on the rim of the blossom. In some cases these may detach and cause satellite spatter. Also note that the movement of the liquid in the dispersion phase is upward and outward.

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 still in motion up and away from the target. This in effect closes the ellipse of the stain. The spines or spine 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 will often observe a small developing droplet. Even at the end of the dispersion phase, surface tension is still a viable force seeking to maintain the connection between the main stain, the spine, and the satellite droplet.

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 now either are overcome by surface tension, resulting in a complete retraction of the liquid, or will overcome the surface tension present in the spine, resulting in the formation of spines and satellite spatter.

At the onset of the retraction phase, it appears that two forces attempt to counter each other. Inertia of the droplet developing at the end of the

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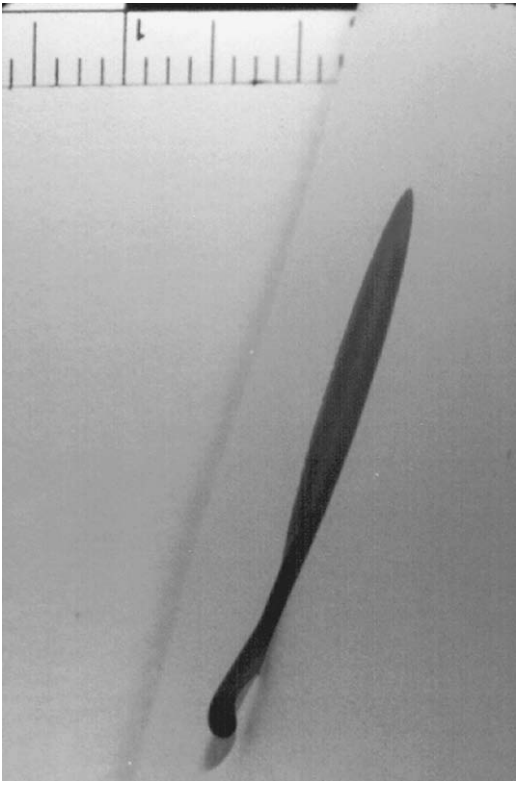

Figure 4.20 A classic wave cast-off developing during the dispersion phase in an acute-angle impact.

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 invariably detach. It is only at this point in the impact that the surface tension of the droplet is actually overcome (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 still evident, in both wet and dried stains (Figure 4.21).

The impact angle has some effect on the 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

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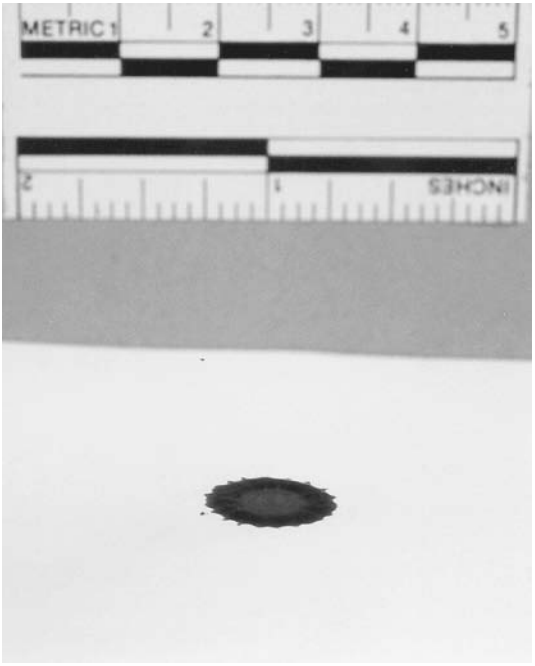

Figure 4.21 Retraction in a droplet impacting at 90°. The blossom we saw previously (Figure 4.19) retracts to the area defined in the displacement phase.

tails" and "claws" we so often see in elliptical stains. Figure 4.22 shows an example of the retraction phase in an acute-angle impact.

Although roughness or irregularity of the target surface have 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 nonwetting nature. On a nonwetting surface, the symmetry of the stain may be irregular as a result of irregular coalescing of the liquid stain. Absorbency of the target also plays a prominent role in affecting this symmetry.

In summing up our observations on the phases of impact, Figure 4.23 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 stain looks as it does.

Liquid-to-Liquid Impacts

For the most part, considering liquid-to-liquid impacts serves little function in bloodstain pattern analysis. It may, however, assist the analyst in understanding the nature of stains such as drip patterns.

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Figure 4.22 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.

The four phases discussed above occur during liquid-to-liquid impacts as well, but with some 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.[43] This is true for impacts into a pool of blood or another drop of blood. Figure 4.24 shows an example of this abnormal blossom development.

As a result 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 pronounced and has been said to resemble

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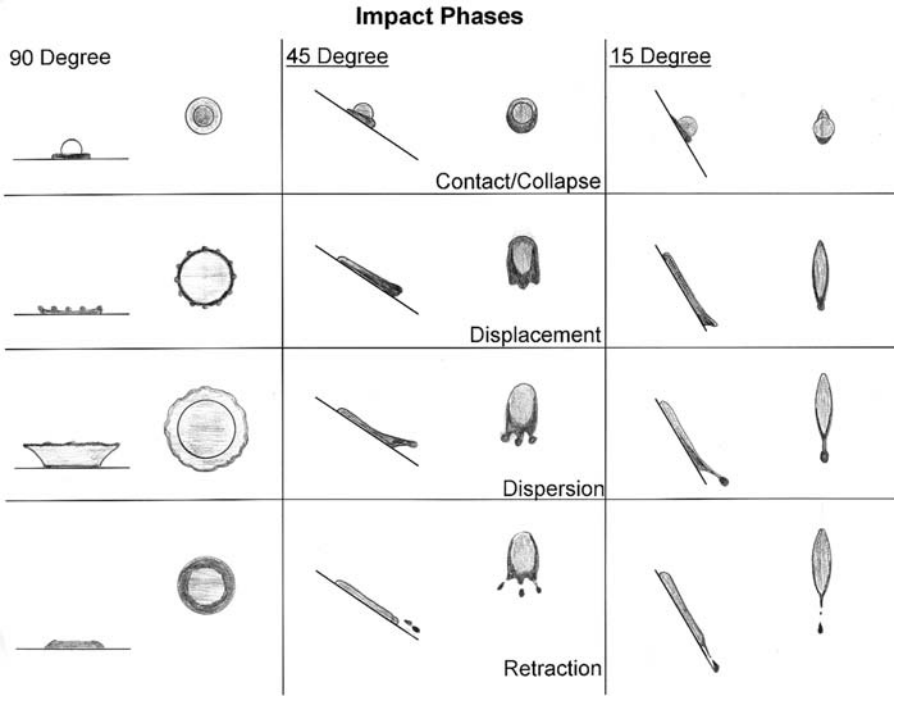

Figure 4.23 A graphic showing all four phases of impact as they occur in varying angles of impact. The drawing on the left side of each box depicts the view from the side; the drawing on the right side of each box depicts the view from overhead. What is evident from this figure is that the collapse of a droplet is far from a simple "drop and burst" effect.

a sea anemone.[44] The dimples are also more pronounced and always result in satellite spatter. In near-90° impacts, these spatter are thrown off in virtually every direction. This result is quite evident in the classic drip pattern, where satellite spatter 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.

Stain Shape and Impact Angle Relationship

The prior discussion of the impact and collapse of the droplet leads us to a general understanding that as a droplet impacts any surface, it collapses in an orderly fashion. This orderly nature, in combination with the angle

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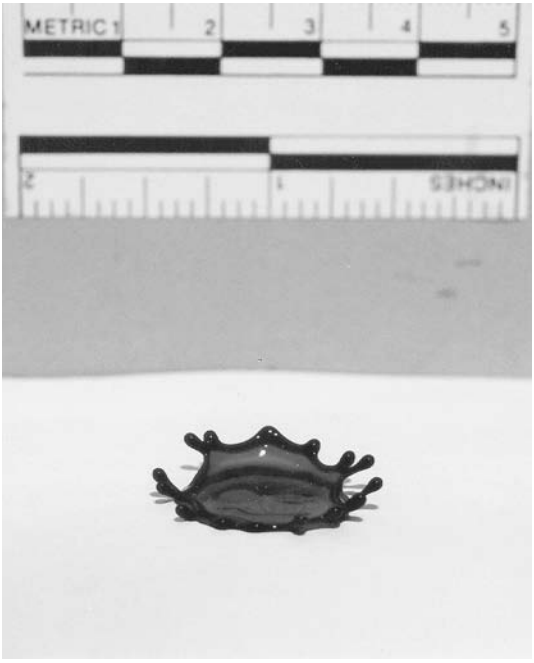

Figure 4.24 Dispersion in a liquid-to-liquid impact. One drop has fallen into another. The increased liquid in the rim often leads to an abnormal outflow of blood and an asymmetrical development of the blossom.

at which the impact occurs, results in a very characteristic shape for the resulting stain. The specific shape (e.g., circular or elliptical) depends on the angle of impact on the target. Droplets impacting at less acute angles (e.g., 80 to 90°) produce circular stains, whereas those impacting at more acute angles create elliptical stains. Figure 4.25 may assist the reader in understanding this relationship. (Refer to Color Figure 2 for examples of the range of droplet shapes possible.*)

The one exception to this relationship is, as Pizzola et al. discovered, when the target itself is in motion at the time of the droplet's collapse. The motion of the target creates a wave cast-off action in and of itself. As a result, a droplet impacting a moving target at 90° mimics a droplet striking a motionless target at a more acute angle (e.g., 20°). As far as physical characteristics go, there are few differences between the two stains created. One difference in the mimic stain is the lack of satellite spatter and spines. Although the mimic stain is often elliptical, it generally does not exhibit spines or satellite spatter.

* Color Figure 2 follows page 134.

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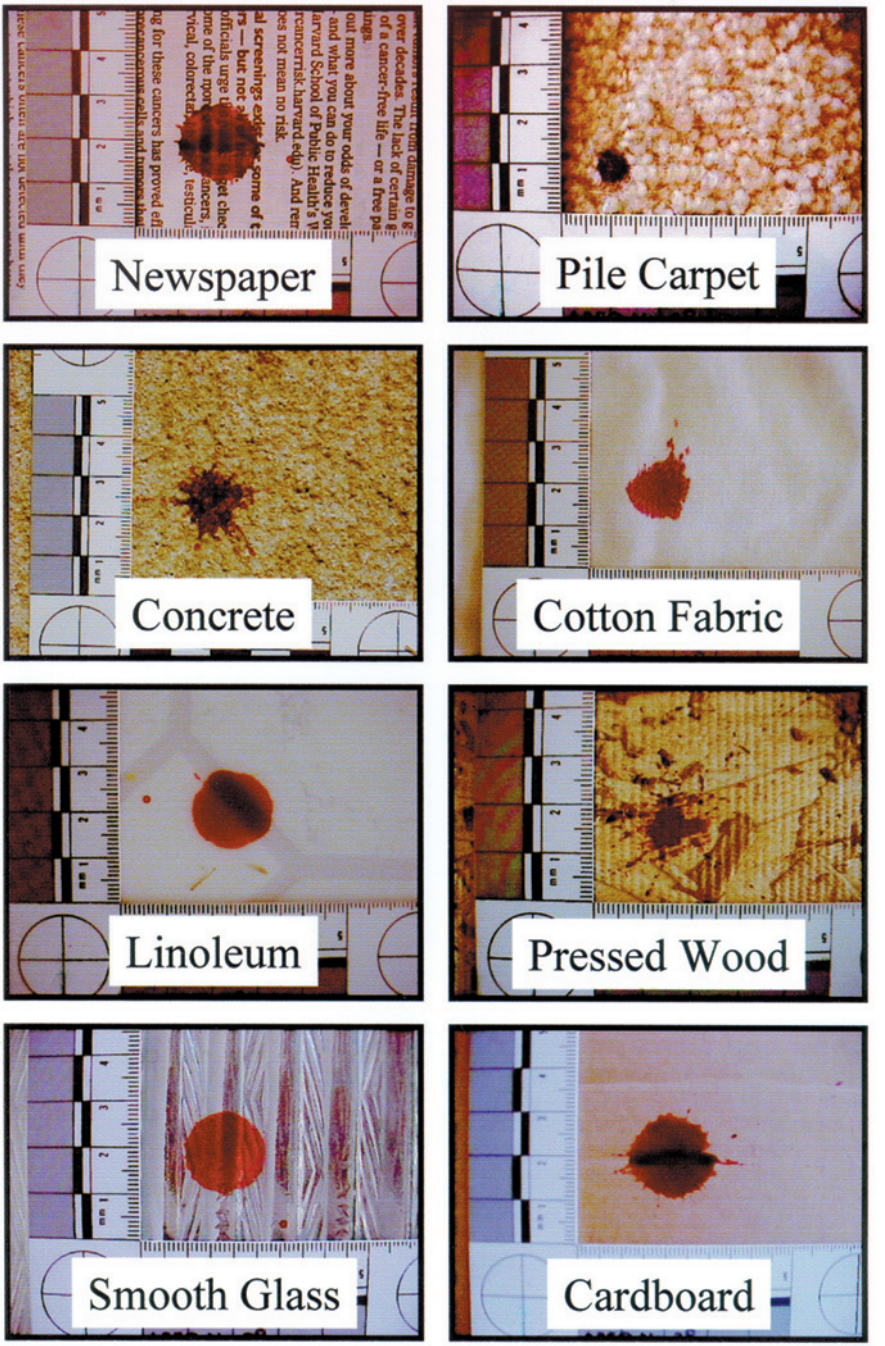

Color Figure 1 Target surface and stain shape. Target surface characteristics affect the size and shape of the resulting stain. The smoother the surface the more likely the stain will be symmetric, with less satellite spatter. The rougher the surface the more likely the stain will be asymmetric.

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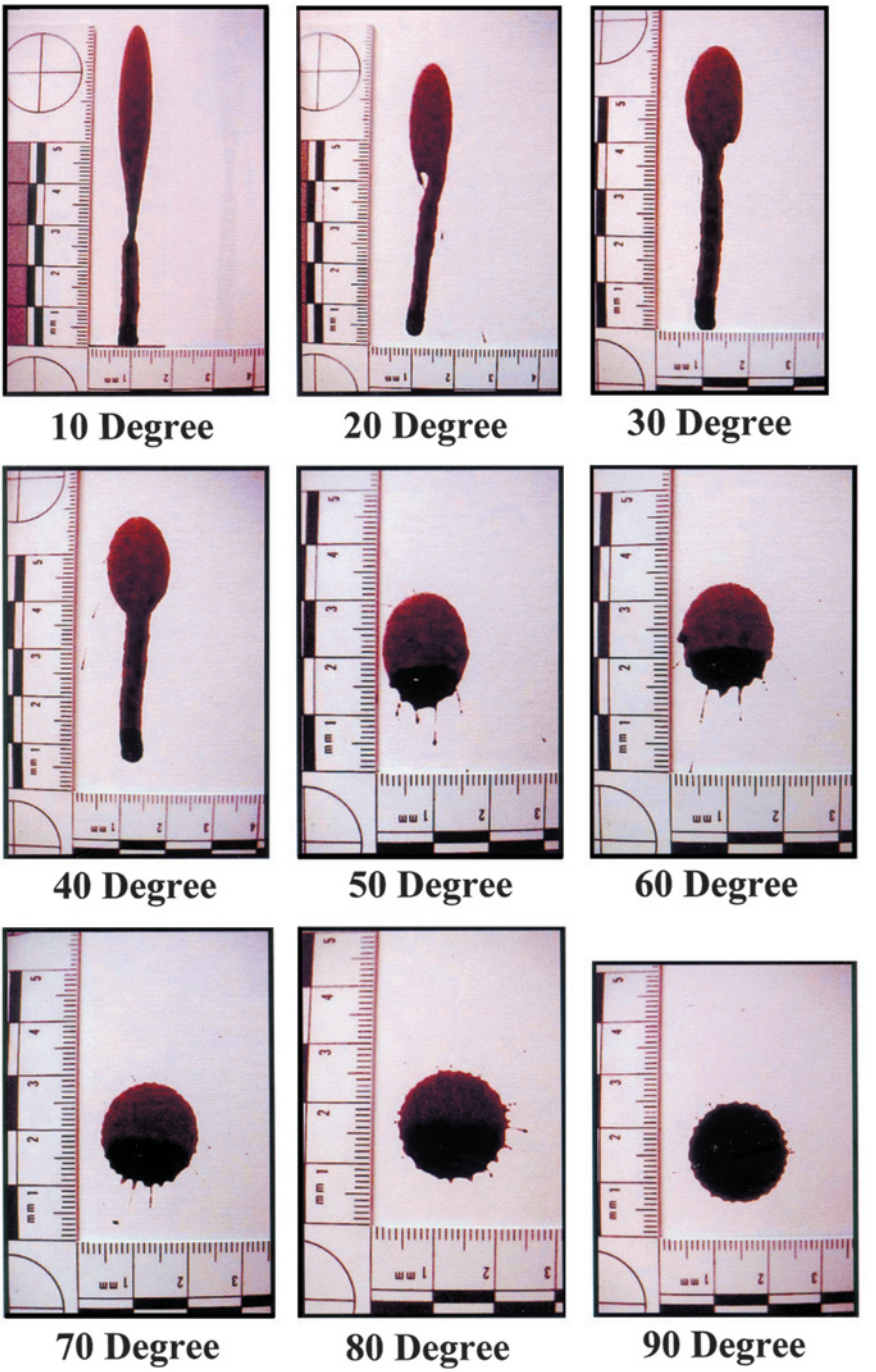

Color Figure 2 Impact angle and stain shape. The range of droplet shapes that result from the varying impact angles. The more elliptical the stain, the more acute the angle of impact. Round stains indicate the impact angle was closer to 90 degrees.

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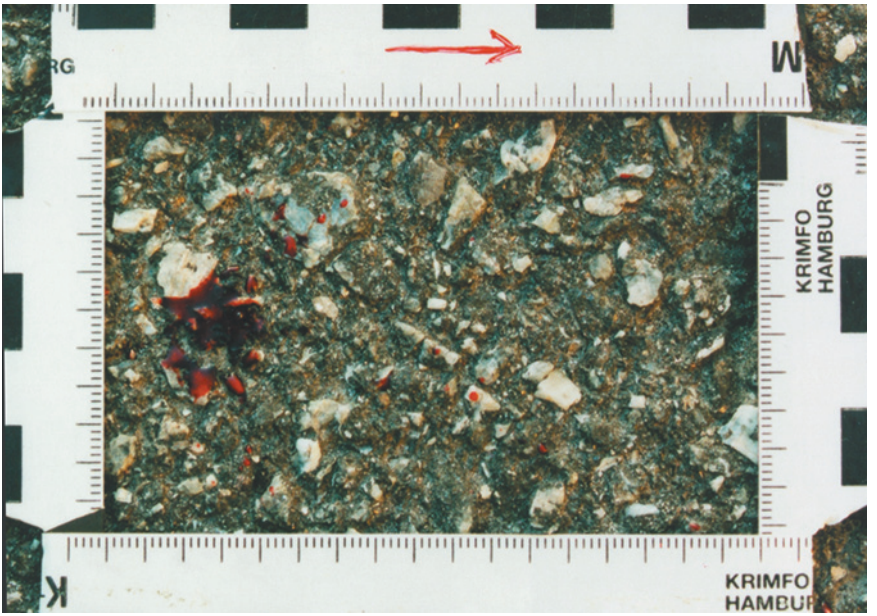
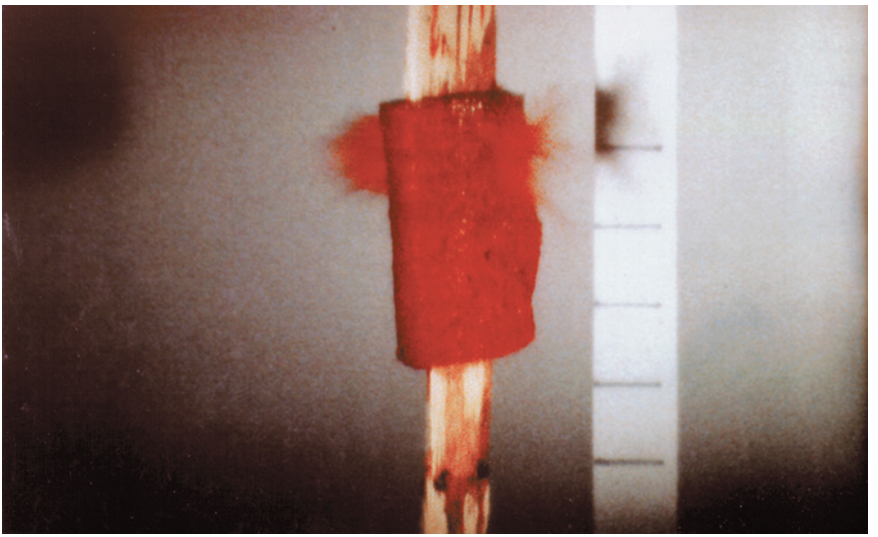


Color Figure 3 Despite an extremely rough and irregular surface, this photograph demonstrates that the analyst can still determine directionality. Small, satellite spatter and spines are visible in this stain indicating directionality from left to right.



Color Figure 4 Forward and back spatter production. In this photograph the development of the cone of spatter is much clearer. Here the bullet has passed through the sponge, moving right to left. Clouds of both back and forward spatter are ejected from the target along its path.

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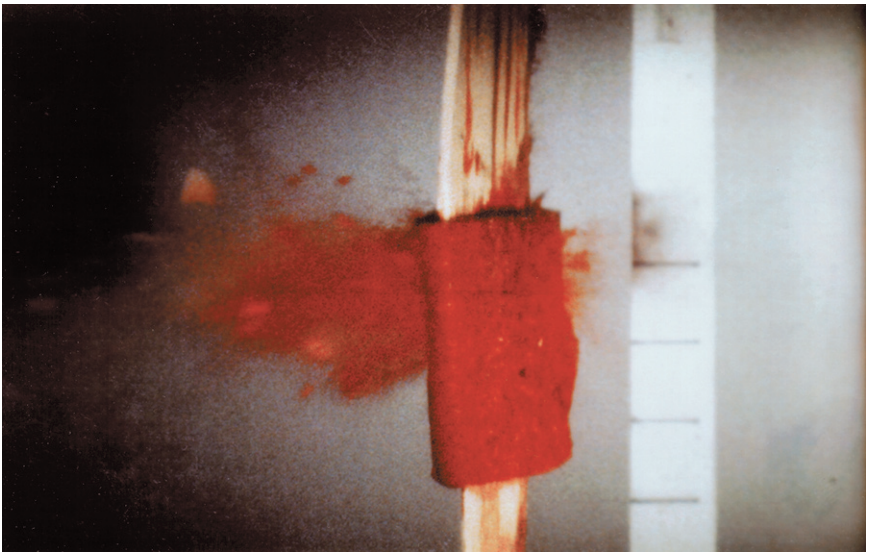

Color Figure 5 In this photo taken milliseconds later, the cloud and cone of forward spatter is well developed and extends out from the target. The cone of back spatter has peaked and is diminishing.

Color Figure 6 Double shot impact spatter. 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. The two wounds to the chest are extremely close together (the arrows point to the wounds). Based on the subject's statement, a minute or less elapsed between the first and second shot.

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Color Figure 7 A view of the ceiling above the victim shown in Color Figure 6. The ceiling was 6 feet from the point where the victim lay facing it. The entire pattern is the result of an abnormal back spatter event associated with multiple wounding to the same area. The first wound filled with blood and when the second shot occurred, this wound was then compressed by the temporary wound cavitation of the second wound, causing a pattern well in excess of the typical volume, size, and distribution found in back spatter events.

Color Figure 8 After being stabbed multiple times in the back, head, neck, and chest, a victim began projecting spatter through his breathing (expiratory blood). The spatter landed on various articles, including this container. (Photograph courtesy of Sandra M. Roberts, Eugene Police Department, Eugene, Oregon.)

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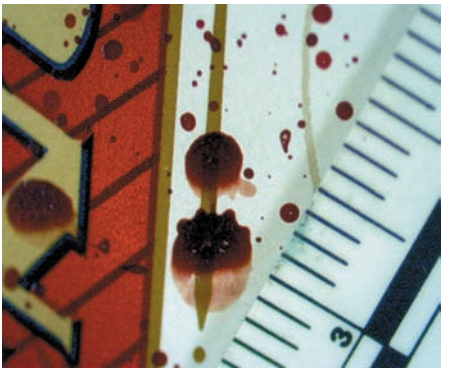

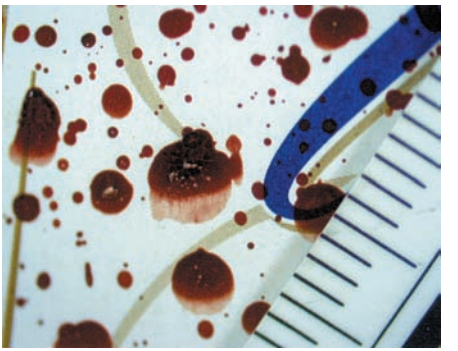

Color Figures 9 (Top left), 10 (Top right), and 11 (Right) Close-up photographs of stains in the overall pattern that exhibit burst air bubbles. Bubble rings are found in expiratory patterns or arterial patterns associated with airway injuries. (Photograph courtesy of Sandra M. Roberts, Eugene Police Department, Eugene, Oregon.)

Color Figure 12 A suspected crime scene in which there was evidence of bloodshed, but also indications that the subject cleaned up the area. The victim, at this point in the investigation, had not yet been found. This is a standard lighting view of the scene prior to the application of luminol. (Photograph courtesy of Ray Clark, Oklahoma City Police Department.)

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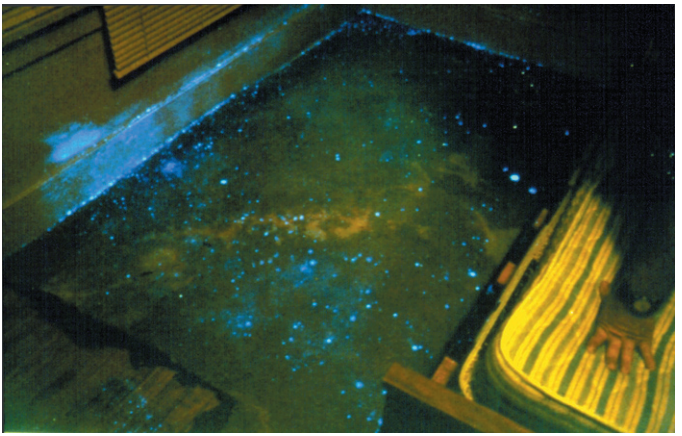

Color Figure 13 The scene in Color Figure 12 following the application of luminol. The blue-green luminescence shows various stains, including wipes, swipes, smears, a drag mark, blood trails, and spatter. (Photograph courtesy of Ray Clark, Oklahoma City Police Department.)

Color Figure 14 (Left) The back stairs of the same crime scene shown in Color Figures 12 and 13. 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.)

Color Figure 15 (Right) Another photograph from inside the scene. Only the large pool of blood was evident without the luminol. Following the luminol application, several additional stains on the carpet and the wipe mark on the wall were discovered. All were caused by the clean-up efforts of the subject. (Photograph courtesy of Ray Clark, Oklahoma City Police Department.)

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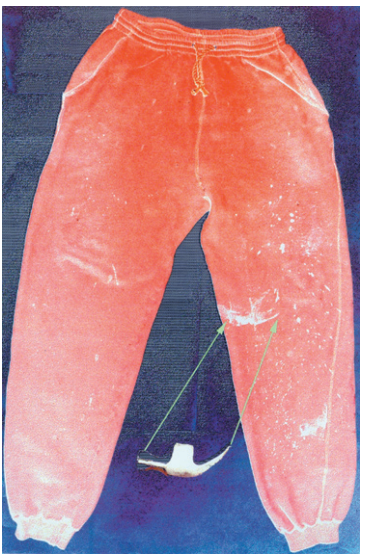
Color Figure 16 A footwear pattern transfer photographed using another lighting technique and luminol. In this method luminescent tape was applied to the back of a clear plastic ruler. Following application of luminol to the scene, the ruler was inserted, giving a visible scale of reference. (Photograph courtesy of T. Daniel Gilliam, Larimer County Sheriff's Department.)



Color Figure 17 (Left) An unaltered 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.)

Color Figure 18 (Right) 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.)

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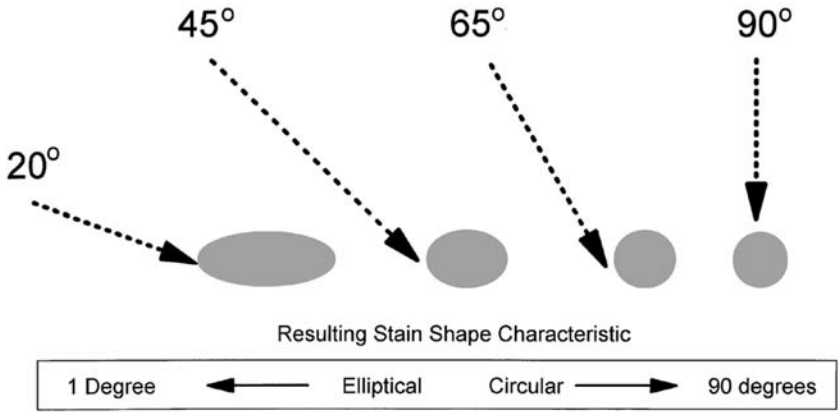

Figure 4.25 Stain shape and impact angle. The orderly collapse of the droplet onto the target produces characteristic shapes depending on the angle of impact. The less acute the angle (e.g., 90°), the more circular the stain. The more acute the angle (e.g., 20°), the more elliptical the resulting stain.

Summary

As we have already stated, it is not absolutely necessary that an analyst understand the overall make-up of blood, the nature of the clotting process, or the manner in which a droplet collapses at impact. The analyst can easily conduct analysis without this specific knowledge. It is not our intent to overcomplicate the discipline, but we do feel this information can better prepare the analyst to conduct analysis.

Understanding the issues involved in blood loss or the manner in which a droplet collapses against a target can only aid analysts in their endeavors. It helps preclude analysts from asserting false cause-and-effect relationships with regard to stain characteristics they observe and the forces that caused those characteristics. Ultimately, this information assists analysts in understanding the bloodshed event.

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Determining Motion and Directionality

5

Establishing the motion involved in bloodshed events and specifically identifying directionality in blood droplets allows the analyst to more fully understand the specific events that occurred during an incident. The nature of this motion is threefold:

- General sequence of events — Where did the event begin? Where did it end?
- Droplet directionality — Identifying the direction from which a given 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 rule exists in bloodstain pattern analysis that is reciprocal to a rule found in arson investigation. In any arson case 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 very likely at or near the point where the violence 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

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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. Amazingly, analysts often overlook the second reason. Once breached, should death follow, nothing but body position prevents the victim from passively bleeding out the contents of the circulatory system. This rule is 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 as a result 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 spatter. These blows create a widening of the wound, which in turn increases the venous blood flow. 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 because 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 when 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 of sequencing actions.

Droplet Directionality

As discussed in Chapter 4, blood impacting a surface acts in a relatively defined fashion. Thus the directionality of a given droplet is usually evident to the analyst. The exceptions to determining directionality are generally carpets and other highly absorbent or irregular surfaces.

As the droplet contacts a surface, it 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

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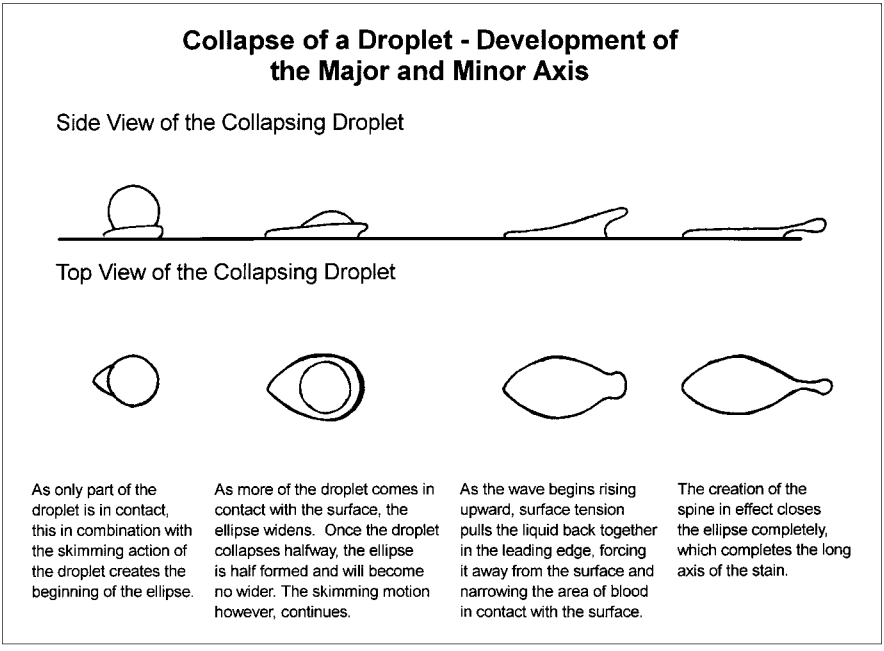

Figure 5.1 A graphic of a collapsing droplet impacting at an acute angle. This demonstrates how the long axis of the ellipse develops and is oriented along the path of travel. Unless impacting at 90°, the axis associated with the direction of travel is always longer as a result of the skimming action of the droplet on the target.

circular stain depending on the angle of impact. Figure 5.1 details how this motion occurs. Whatever the shape, the resulting stain (unless impacting at 90°) will have both a major and a minor axis. The major axis (longest axis) is always aligned with the path of the droplet.

It is the major axis of this circle or ellipse that begins our definition of the droplet's directionality. This axis defines a line with two possible droplet flight paths. In viewing the stain, the analyst must seek information to eliminate one of the two. Satellite stains, scallops, or spines provide the analyst with means for making this elimination and identifying the direction of travel (Figure 5.2).

As the discussion of dispersion in Chapter 4 explained, when the droplet collapses a blossom effect begins. The exact nature of this blossom is defined by both the angle of impact and the nature of the target surface. As this blossom develops, the surface tension of the liquid pulls the blood into distinct dimples in the leading edge of the blossom structure. These dimples in many instances break from the blossom structure, creating satellite stains. Whether these dimples break completely free or simply form spines or

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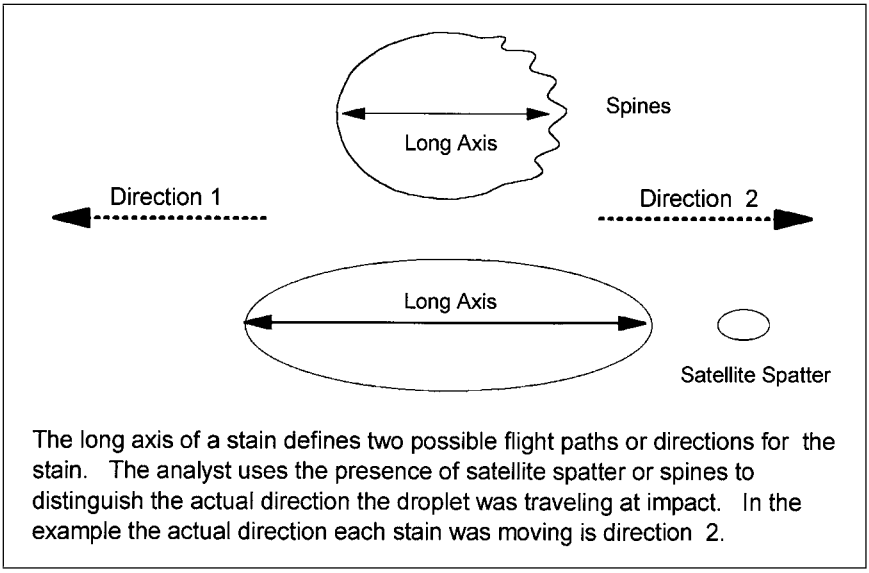

Figure 5.2 The presence of spines, scallops, spatter, or tails help the analyst identify the path the droplet was traveling at impact. These structures are found opposite (or at least are concentrated opposite) the side of the stain that impacted first.

scallops, their presence in relationship to the parent stain defines the motion of the droplet at impact.

Obviously, the path these spines and satellite droplets follow is defined by the redirection of the blood as it impacts. In instances of 75 to 90° impacts (the more circular stains), spines and satellite stains may be evident all around the parent stain (Figures 5.3 and 5.4). As this angle decreases, however, one side will show greater evidence of both. By considering the longest axis of the stain, and highest concentration of satellite stains or spines on one side, the analyst can identify the droplet's general direction of travel.

A measure of caution is always in order when considering 75 to 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 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, clarity of this direction increases as the impact angle decreases. 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. The direction evident in the shape of such spines and satellite stains allows us to more accurately define the path of travel (Figure 5.5).

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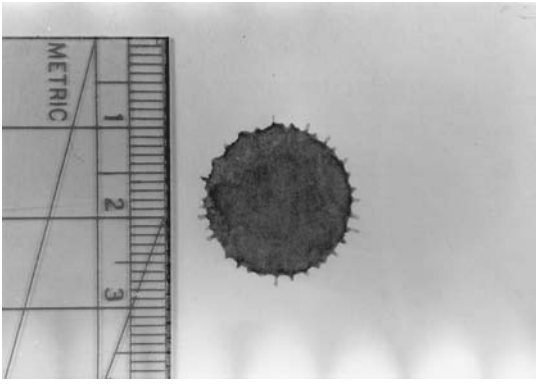

Figure 5.3 A 90° impact. Small scallops appear around the entire periphery of the stain.

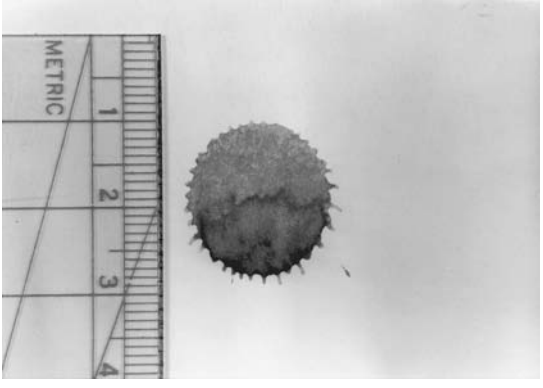

Figure 5.4 A 70° impact. Note the greater concentration of large scallops on one side of the stain. They are opposite the droplet's origin and point in the general direction the droplet was traveling. Directionality in circular stains is not as clear as in elliptical stains because the spines are not concentrated along a single vector.

For impacts at less than a 40° angle, 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 5.1). Such an impact is likely to create a single satellite stain (Figure 5.6). This satellite 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 stain usually matches that of the parent stain. Minor redirection of the satellite may occur as a result of surface irregularities present on the target, resulting

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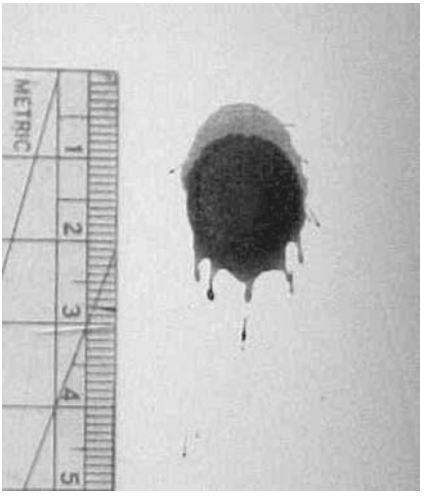

Figure 5.5 A 50° impact. In this instance the scallops have spawned significant tadpole tails. Once again the tails align with the long axis of the stain and point in the direction the droplet was traveling. Although directionality is not as specific as when we find a single tail, the analyst can clearly define the droplet's directionality.

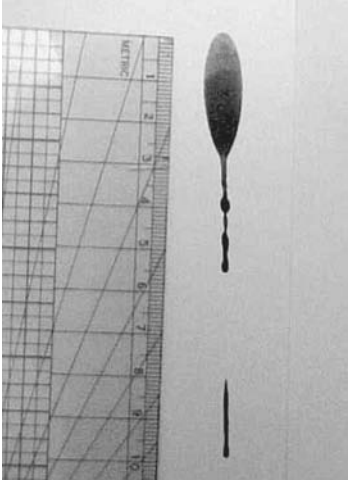

Figure 5.6 A 20° impact. This stain has a tail and detached satellite. In combination with the long axis of the elliptically shaped stain, it provides a very specific indication of the droplet's path of travel.

in a spine or tail at an odd angle to the parent stain. In such cases the long axis of the parent remains the best indicator of directionality.

When considering satellite stains and their tails, parabola effects may also be evident. This is particularly true for stains impacting vertical targets. These effects may place the satellite somewhat off-line from its true path. This

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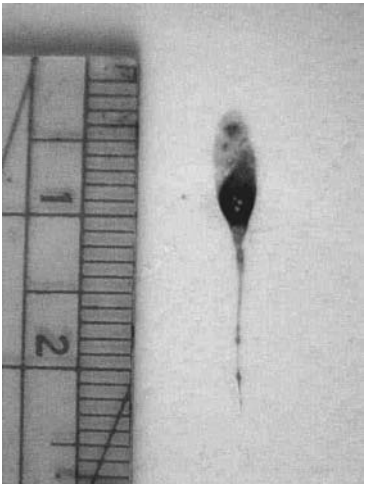

Figure 5.7 A stain with a detached satellite that is not in proximity to the parent stain. Occasionally the satellite will be detached and not be anywhere near the parent stain. The spine or tail that spawned the satellite, however, will provide all the necessary information to identify the direction of travel.

condition is easy to spot and will not distinctly challenge the analyst in determining the droplet's true directionality.

Even in cases where the satellite stain is not immediately evident (e.g., perhaps covered by surrounding bloodstains), the spine from which it was created will often be evident on the parent stain (Figure 5.7).

If you recall our discussion of parent and satellite stains in Chapter 3, we made it clear that it is important to differentiate between the two. As evident in Figure 5.6, both the parent and satellite may have a tail. The parent tail points in the direction of the droplet's travel; the satellite tail points 180° opposite to the droplet's direction of travel. 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 because their tails clearly align with one another.

Thus the presence of such satellite stains, scallops, and/or a spine helps define the direction of travel for the parent stain. 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), aligning it with any tail, scallops, or satellite (Figure 5.8).

As should be evident, a rough target can impair our ability to read a stain, but rough or irregular surfaces alone, particularly in instances of the more elliptical stains, do not prevent us from defining directionality. Consider a worst case, such as a stain found on asphalt. The stain may well be disturbed (when compared to one impacting a smooth surface), but the directionality is still evident. The irregular outflow of blood in the parent

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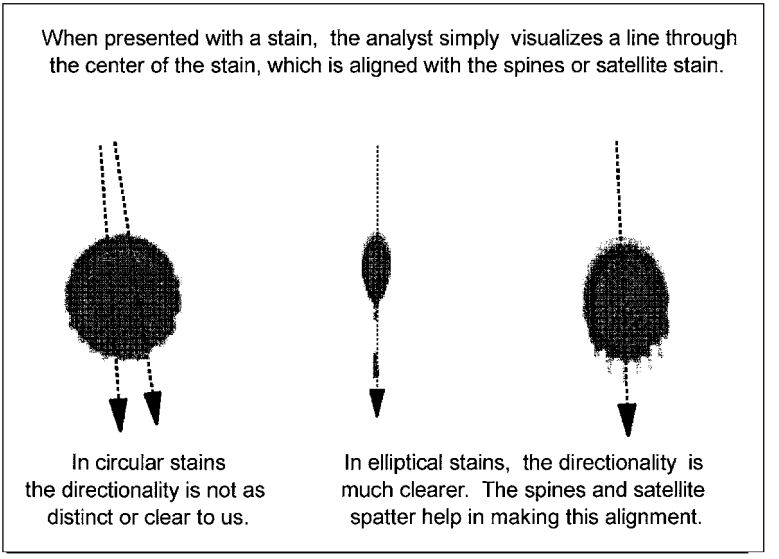

Figure 5.8 To visualize or demonstrate directionality in a droplet the analyst simply draws a line down the long axis of the stain, splitting it into two equal parts. This line is oriented to the scallops, spines, or satellite stains.

stain during the displacement and dispersion phases is insufficient to mask the directionality entirely. (See Color Figure 3.*)

We can summarize our discussion as follows:

- The more elliptical the stain, the more accurate the definition of directionality.
- Less elliptical stains demand a cautionary approach.
- The smoother the target, the less likely irregularities will occur that might mask the directionality.

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. Although not common, 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

* Color Figure 3 follows page 134.

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the angle of impact cautiously. Obviously, motion of a target makes it difficult at best to establish directionality. If one cannot establish the target's exact position at the moment the droplet struck, the stain itself tells the analyst little if anything.

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 move, or bloody items are moved within a scene, blood trails are likely to occur. The drops strike the surrounding floors and surfaces, and as they break free, they are moving with the same momentum and generally in the same direction as the item from which they fell. The combination of gravity and this momentum cause the drops to impact the ground at varying angles. The resulting stains in the blood trail show evidence of this angle and its direction. This directionality allows the investigator to determine in which direction the trail leads (Figure 5.9). Figure 5.10 is an example of a typical blood trail.

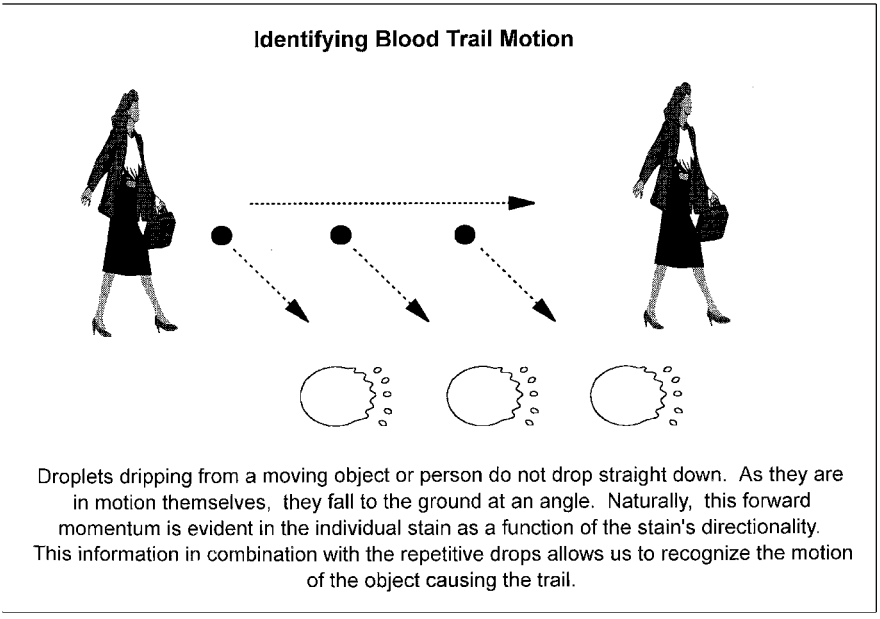

Figure 5.9 Blood trail motion is defined by considering the directionality of the individual drops present in the blood trail pattern.

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Figure 5.10 A typical blood trail pattern. Although the photograph doesn't allow us to see the close-up detail of spines and scallops, on closer examination this information is always evident.

Figure 5.11 depicts a blood trail on a coarse, irregular surface. Nevertheless, directionality is very evident in the resulting bloodstains. Figures 5.12 and 5.13 depict individual stains, with elliptical shapes. Although the stains are anything but symmetrical, the direction the droplets were moving at impact is very apparent. Figures 5.14 and 5.15 also depict individual stains found further along the blood trail. The stains here are far more circular, and given the stain by itself, no directionality would be evident. By considering stains along the entire length of the trail, one can usually establish the direction of travel.

Figures 5.12 through 5.15 also assist in establishing the pace or speed of the item creating the blood trail. The more elliptical stains (Figures 5.12 and 5.13) indicate a greater forward velocity than those in Figures 5.14 and 5.15. 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-shaped stains at different points along the trail may well indicate a change in the speed at which the item was

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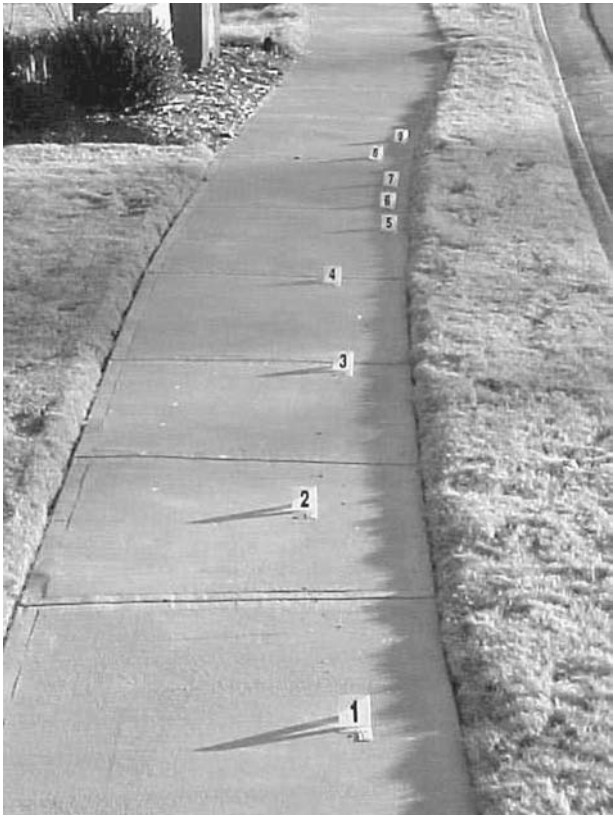

Figure 5.11 A blood trail pattern on concrete. The photo tents will allow us to orient the location of specific stains and their shapes to the pattern as a whole.

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.

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 in 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. The stains often become disturbed by these 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 5.16 shows a large-volume wipe present on a kitchen floor.

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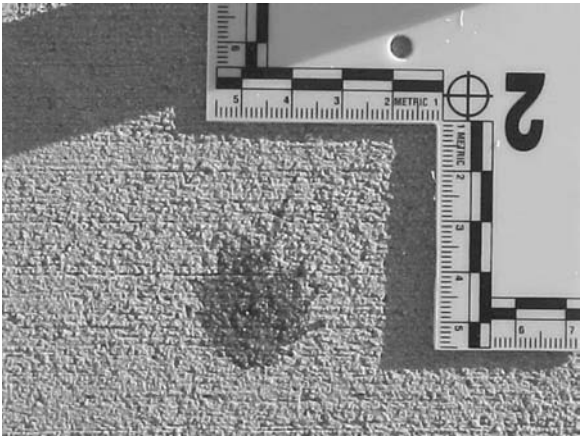

Figure 5.12 Stain 2 from the previous pattern (Figure 5.11). An elliptical stain with evident directionality. The directionality evident for the pattern in Figure 5.11 is away from the camera.

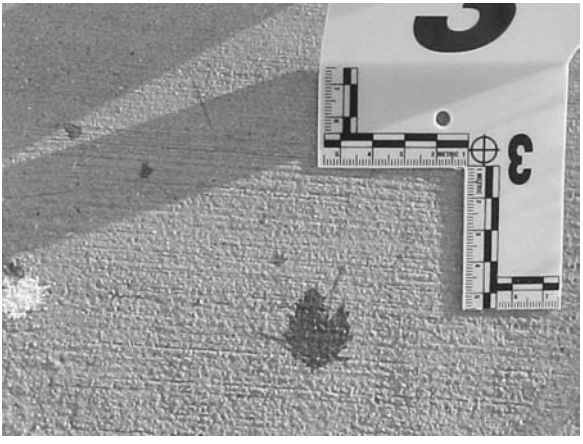

Figure 5.13 Stain 3 from the pattern in Figure 5.11. This stain is significantly irregular in its shape. Satellite spatter are still evident to identify directionality. Note the satellite spine approximately 15 mm to the right of the photo tent.

Figure 5.17 is a closer view of detail within the stain. Another example often encountered 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 clear and specific (Figure 5.18).

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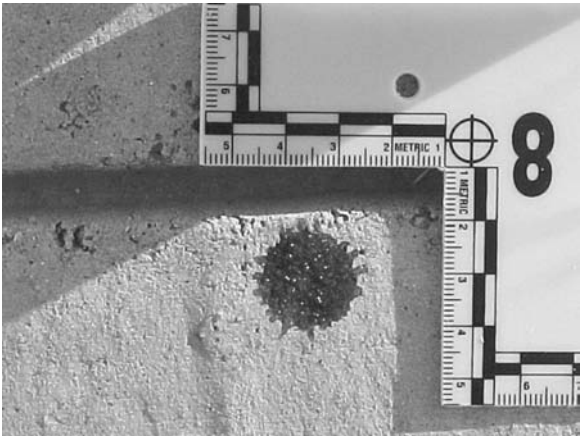

Figure 5.14 A circular stain from the pattern in Figure 5.11. Directionality in this stain is not evident, but the change in shape does indicate a change in the speed of the item dripping the blood. This more circular stain indicates the item was moving more slowly at this point than when dripping at the points indicated in Figures 5.12 and 5.13.

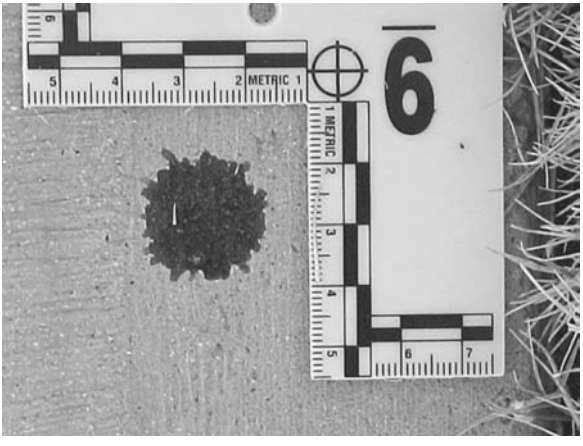

Figure 5.15 Another circular stain from the pattern in Figure 5.11. Once again directionality is not evident due to the irregular surface. Taken as a single stain, the shape is not helpful, but by considering the shapes evident along the whole pattern we can still be confident of the direction of travel.

In a situation involving a swipe, the direction may not be as evident. Depending on how the bloody object came 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.

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Figure 5.16 A large-volume wipe pattern on a floor. The obvious displacement of blood allows us to determine in which direction the motion of the wipe occurred.

Generally, we seek 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, obviously the volume available to be swiped and smeared against the target decreases. As a result, the appearance of the final portion of the swipe often has this "thinning" characteristic.

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. Such trailers are commonly referred to as "feathering" of the stain (Figure 5.19). 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 their evaluation. This is particularly true in instances of hair swipes. Feathering on a single side of the stain is usually a significant characteristic that allows for easy identification of the motion involved (Figure 5.20).

Recently, some analysts have claimed that "feathering" is not a functional means of evaluating directionality of the 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

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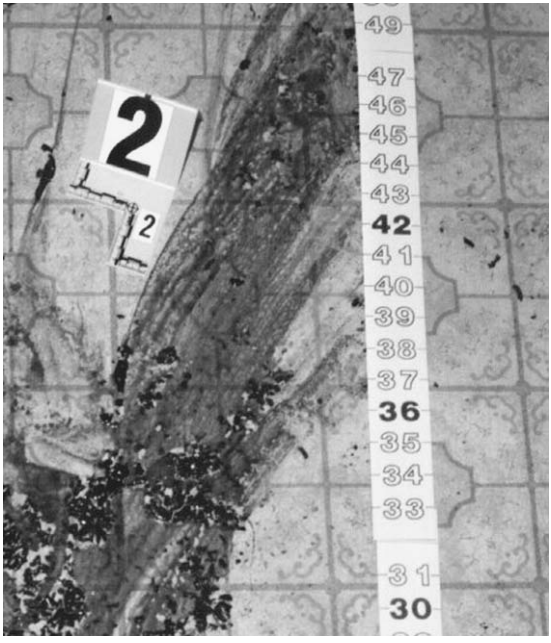

Figure 5.17 A close-up of detail from the pattern in Figure 5.16. The displacement of blood and the feathering and thinning of the stain all point to the direction of the wipe.

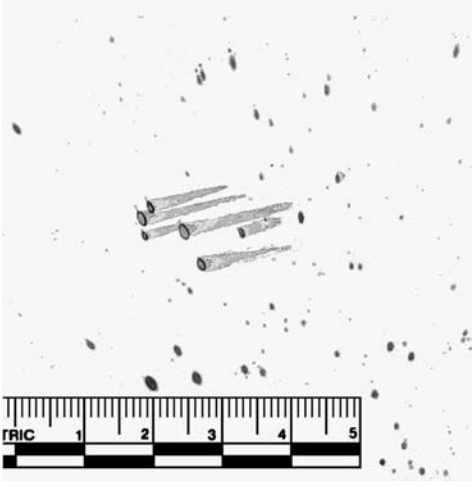

Figure 5.18 A spatter pattern that was wiped through after deposit. The wiping and displacement of the liquid blood leaves obvious evidence of a left-to-right motion by whatever caused the wipe.

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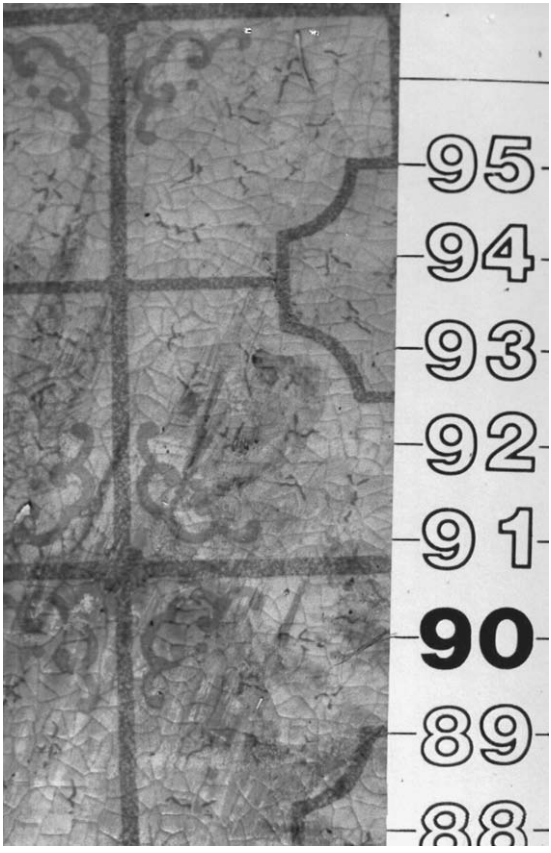

Figure 5.19 A swipe pattern on a vinyl floor. The linear features in the stain that run diagonally to the vinyl pattern are often referred to as feathering. The points of these features combined with a thinning of the stain indicate the motion of the swipe as up and to the right.

and wipe, including displacement of the volume of blood and evaluation of the "gritty" nature of the blood based on drying characteristics.[1]

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 for defining directionality. Depending on the means of application of the swiping or wiping object, displacement of the blood can occur in any direction. The gritty nature of blood is not a characteristic we consider valid for defining motion in a stain.

We know of no studies or reports that would suggest that the feathering characteristic is not a viable means of evaluation. Based on experience, we feel comfortable stating that feathering must be considered in relation to all other characteristics of the stain. Nevertheless, when the stain is considered

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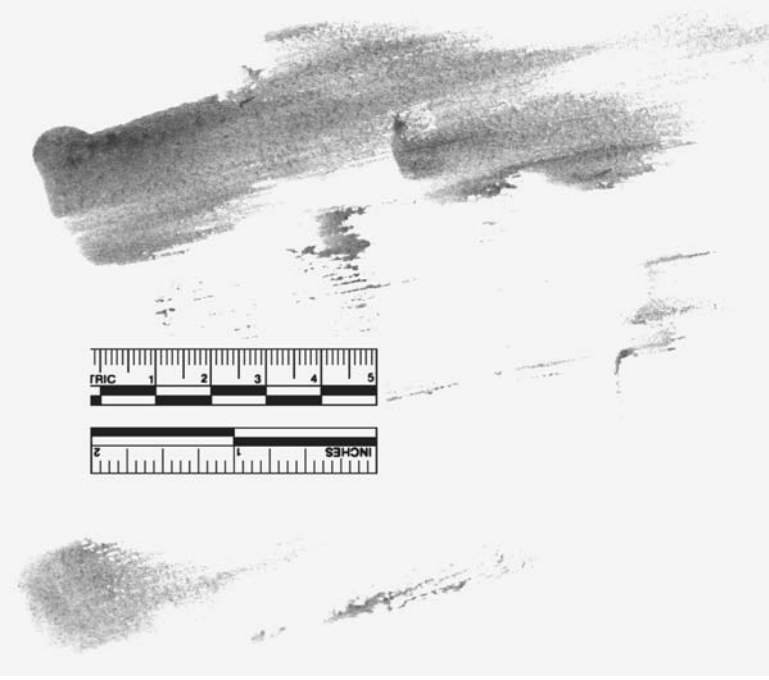

Figure 5.20 A hand swipe pattern. Note the feathering on the right edges of the primary stains in the pattern. Feathering on a single side of a swipe pattern is usually a significant characteristic in terms of defining directionality. In this instance the motion was left to right and slightly upward.

in a holistic fashion, feathering is a significant characteristic for defining direction of movement of the swiping object.

Thus wipes and swipes assist in defining motion and may also help to identify the nature of the item that was in motion. We will discuss this latter aspect in greater detail in Chapter 8.

Repetitive Pattern Transfers

Repetitive transfer patterns 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 cause of such patterns. The item comes in contact with a blood source, as when a shod foot steps into a puddle of blood (Figure 5.21). As the individual walks, blood is deposited each time the shoe contacts the target until it is depleted.

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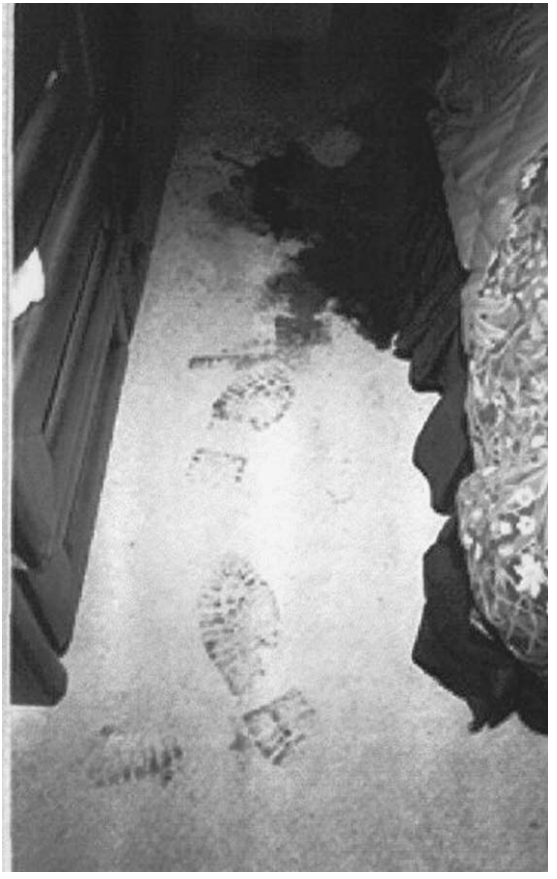

Figure 5.21 A repetitive pattern transfer resulting from a shoe stepping into the large pool of blood at the top of the photograph. The wearer then stepped backwards.

To define this motion one must evaluate 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.

When attempting to identify the patterns present in such trails with 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.

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Figure 5.22 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.

Flows

Blood flows also provide critical information about motion. Obviously, blood flows will obey the laws of physical science, specifically gravity. Of concern to the analyst are flows that indicate body movement after the flow began. Flows on the body that are irregular or defy expectations with regard to gravity may point to earlier positions of the victim (Figure 5.22).

Another irregular flow 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. Patterns of this nature are discussed again in Chapter 8, along with a figure example.

Summary

Blood and bloodstains provide the analyst with excellent indications about motion and action. Understanding the minor nuances of directionality requires little effort because we observe liquid droplet behavior daily.

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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 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 simple.

We hope it is obvious to the reader that motion is truly the most basic indication bloodstains provide at the crime scene. The amount of detail present in this type of evidence supports our ability to link and sequence the overall set of events defining any given incident.

Reference

1. Hoymeyer, Jane M., Ph.D., Blood Evidence, IAI Workshop Notes, unpublished.

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Determining the Point of Convergence and the Point of Origin

6

Our prior discussion of directionality and the evaluation of the path a given droplet was traveling logically leads us to the next step: defining where the droplet came from and determining what common convergence point several spatters may or may not have.

We can determine the point or area of origin for stains in three ways:

- Viewing the spatter from overhead to locate a point of convergence
- Viewing the spatter both from overhead and from a side view
- Viewing the spatter using either forensic software or the stringing technique

Depending on the specific questions raised about a given spatter pattern, the needs of the analyst may be different. Thus, an overhead point of convergence analysis may be sufficient for some circumstances. At other times the analyst may require more detailed information, demanding the use of the point of origin evaluation methods.

Determining Point of Convergence from Overhead

In each instance where we can define a stain's path, if we simply draw a reverse azimuth (i.e., a line that extends backward along the path the droplet was following), we can be reasonably sure the droplet originated somewhere along this avenue.

For the moment, let's limit our discussion to this single overhead viewpoint. Remember, our perspective is a bird's-eye view of the target

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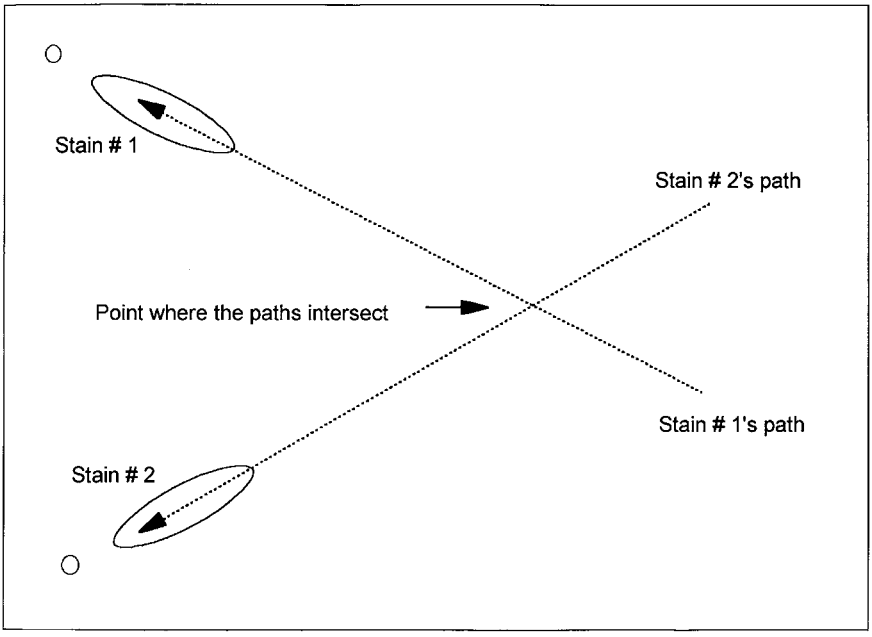

Figure 6.1 By following the reverse vector of each droplet to the point where they intersect, we can establish a probable point of convergence in two dimensions.

on which we find the spatter. 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 will affect the droplet only in the path of its parabola.[1]

For example, in Figure 6.1, 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. As an example, if the box for Figure 6.1 represented the room boundaries and the possible reverse path for Stain #1 extends 13 ft, then the drop's origin may lie anywhere within those 13 ft. With only one stain, the resulting parameter of possible points of origin is very wide.

If we consider a second stain, as in Figure 6.1, 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.

By limiting ourselves to this overhead dimension, we certainly gain simplicity in the evaluation. We also gain an inherent difficulty. If our circumstances limit us to only a few stains, it is always possible they are the result

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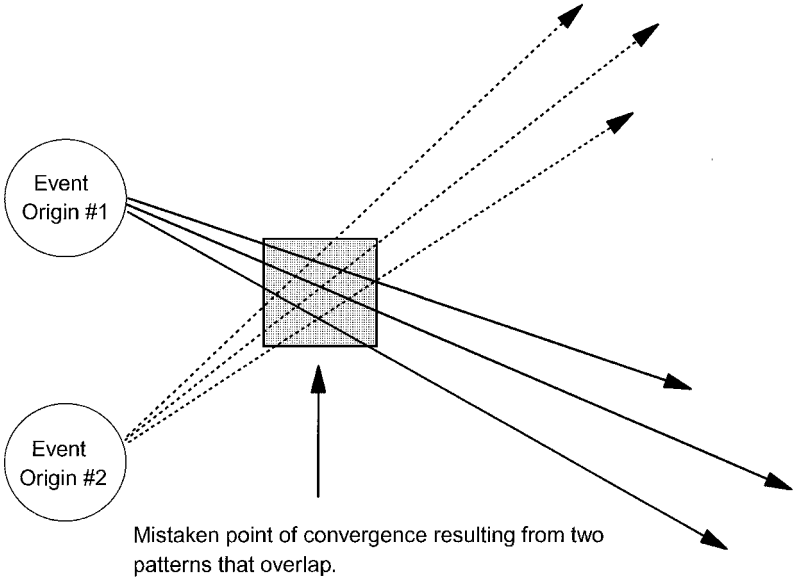

Figure 6.2 In addition to the possibility of two stains having a coincidental intersecting point, it is also possible for two patterns to overlap in this fashion. If this condition is not considered it might well result in a mistaken point of convergence for both patterns.

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 are simply coincidental and have no investigative significance.

If the stains are widespread within a scene and show no common convergence point, we would easily recognize them as resulting from separate actions. If found in proximity to one another, the likelihood increases of a coincidental convergence of the flight paths along their reverse paths. Unfortunately, we may choose to read this convergence as a single point of origin for both stains. With only a few stains to work with, it may be difficult to recognize such an error.

The same is certainly true when viewing two adjacent patterns. We may see a coincidental convergence area for two patterns and read this as the source for both. Figure 6.2 illustrates the possible error when viewing patterns from two closely located impacts.

As the number of evaluated stains available to us increases, so too does our level of confidence. The more paths that intersect a given point, the more likely it is a true point of convergence. In circumstances of multiple events with the spatter intermixed, the primary convergence point should still be evident. In this situation, paths may cross at several locations, but those

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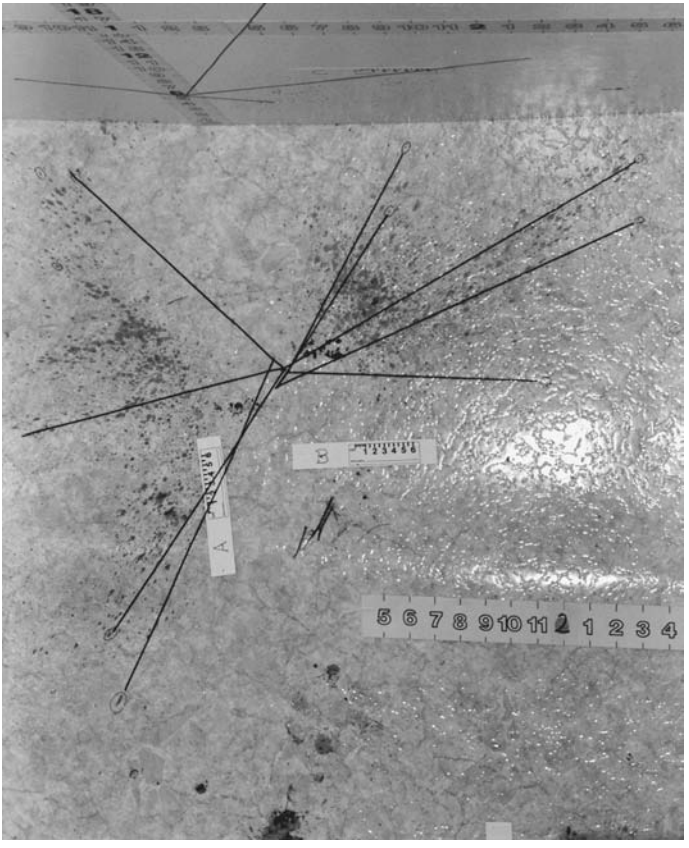

Figure 6.3 An example of using graphic tape to demonstrate the point of convergence in a spatter pattern.

locations where we find clusters of intersecting paths will establish the primary convergence points of the spatter involved.

What this overhead method does not establish is the location above the point of convergence where the spatter originated. In an overhead approach we establish only the point of convergence on a single plane and accept that 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.

The overhead technique, however, is still effective. Used in conjunction with Toby Wolson's[2] technique of roadmapping, which is discussed later in this book, it represents a graphic method of portraying the point within the scene from which the droplets originate (Figure 6.3). We can also use this method in a limited fashion on vertical surfaces, but we must give obvious consideration to the droplet's parabola.

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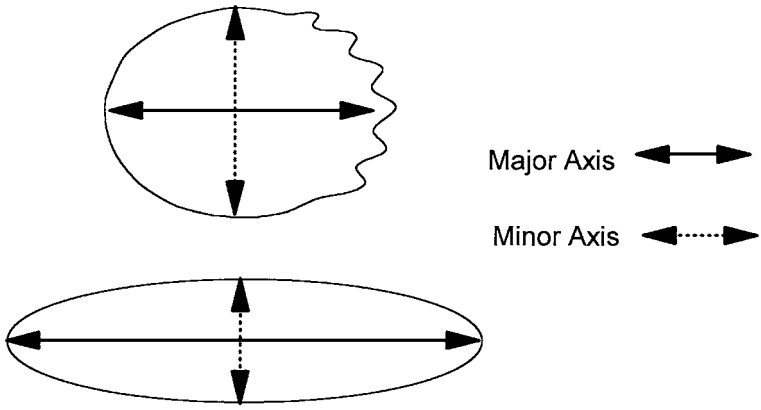

Figure 6.4 Our concept of a "well-formed" stain means simply that if we divide the stain along its major or minor axis, the opposite halves would be generally equal to each other.

Up to this point, we've 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 our point of convergence. To establish with a greater degree of accuracy a specific location above the point of convergence, we use a side-view approach of the target. This requires including the stain's impact angle in the analysis. Before we can consider this second method of defining the point of origin, we must define the individual droplet's impact angle.

Determining Impact Angles

We generally credit Dr. Victor Balthazard with having recognized that a relationship exists between the length and width of the resulting stain and the angle at which the droplet impacts. MacDonell later refined this concept, applying the length-to-width ratio in conjunction with specific math functions (e.g., sine). 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] A well-formed stain is one that, if divided along the major or minor axis, would result in two halves that are approximately equal to each other (Figure 6.4).

To apply the impact angle formula it is important to understand that in right triangles certain relationships exist between the angles of the triangle and the lengths of its sides. These relationships are trigonometric functions such as the sine, cosine, and tangent. These relationships in no way depend

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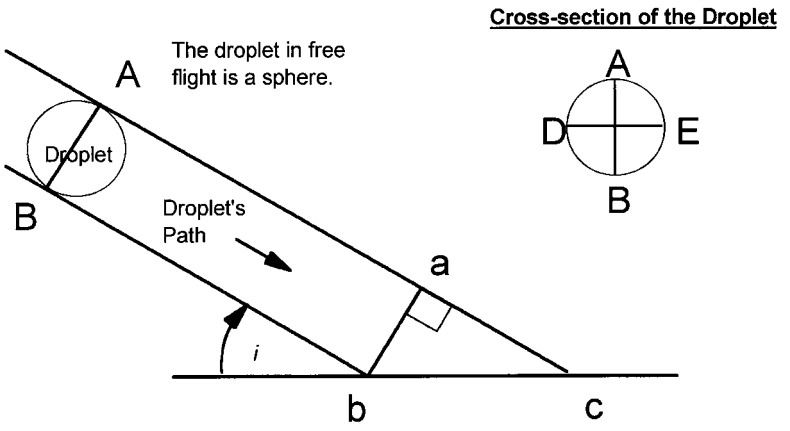

Figure 6.5 The relationship of the droplet to an imagined right triangle. Using the sine function and this relationship, the analyst can establish the angle of i. This is the droplet's impact angle.

on the factors found at the crime scene; they are mathematical in nature. Thus we can draw 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 6.5 outlines how this triangle might look. A blood droplet in flight is in the shape of a sphere.* Therefore, in viewing Figure 6.5, 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 (Figure 6.6). 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.

As a result of this analogy we have two known quantities from our crime scene that we can apply to a formula. By measuring the stain's length and width and applying them to the following formula, the droplet's impact angle becomes evident:

$$\text{sine } i = \text{width (ab)}/\text{length (bc)} \quad (1)$$

$$\text{inverse sine (ASN) } i = \text{impact angle} \quad (2)$$

* Although one might infer from the drawing in Figure 6.5 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.

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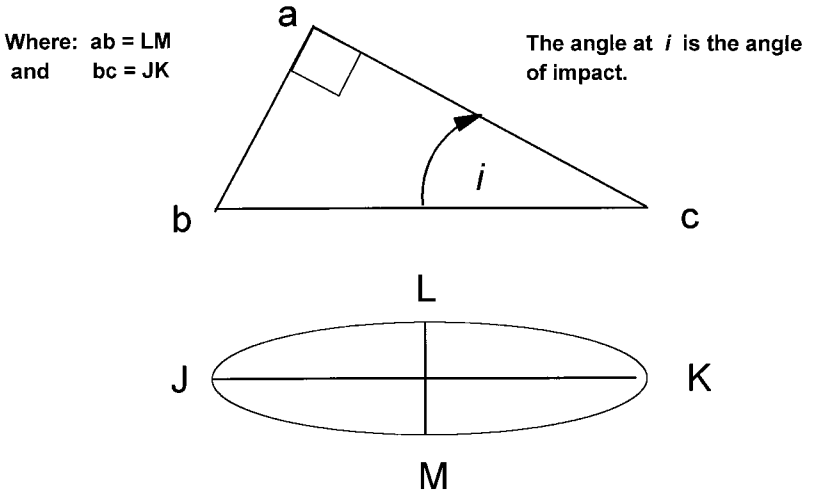

Figure 6.6 We can draw an analogy between the right triangle formed in Figure 6.5 and our bloodstain. Line ab is analogous to the line LM, as is bc to JK. Thus the length and width of the stain are quantities we can apply using the sine function to determine the impact angle (i).

Example:

Width = 3 mm
Length = 5 mm
0.6 (sine *i*) = 3/5 (width/length)
Inverse sine *i* (0.6) = 36.8
Impact angle = approx. 36–37°

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 ballistics and oscillations in the droplet preclude us from accepting this angle as absolute. As a general rule, the angle indicated is probably accurate to within 5 to 7°.

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-to-width ratio chart (Figure 6.7). The analyst divides the measured length of the stain by the width, resulting in a number greater than 1. (If the result is less than 1, you've reversed the length and width in the formula.) Using the result, the analyst locates the corresponding number on the vertical axis of the chart. Where the line intersects this point, one simply reads the angle listed on the horizontal axis.

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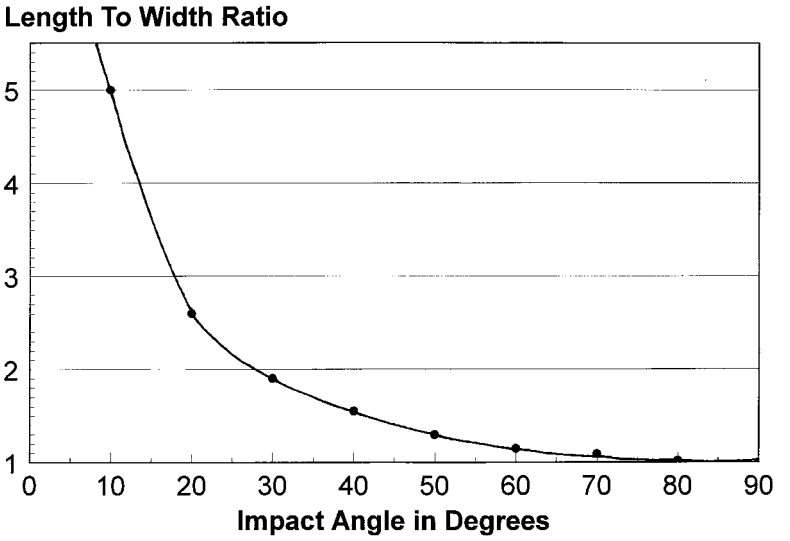

Figure 6.7 A length-to-width ratio chart. By dividing the length of the stain by the width, we generate a number that is always greater than 1. The analyst finds this number on the vertical axis then, reading to the right, locates the corresponding point where the graph line intersects. The angle listed below this point is the approximate impact angle. For example, the length-to-width ratio of 1.9 equates to a 30° impact angle.

The second method involves dividing the width of the stain by the length and comparing this number to a sine function table (Figure 6.8). In this instance the result will 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 calculator.

Stain Measurement

Measuring the stain is obviously critical, because this provides the analyst with a length and width. The analyst measures only the main body of the stain, excluding any portion of the satellite and spine present in the stain. To accomplish this, one might 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 (Figure 6.9).

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 5-mm length, a 4-mm width, and a 0.5-mm scalloped tail. Given such a stain, the following is possible:

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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 6.8 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 in the sine column of the chart. The number adjacent to this lists the degree of the impact angle. For example, a 0.5 width-to-length ratio equates to a 30° impact angle.

Correct Measurement and Evaluation		*Incorrect Measurement and Skewed Evaluation*	
Length:	5 mm	Length:	5 mm plus 0.5-mm scallop
Width:	4 mm	Width:	4 mm
Impact angle:	53°	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

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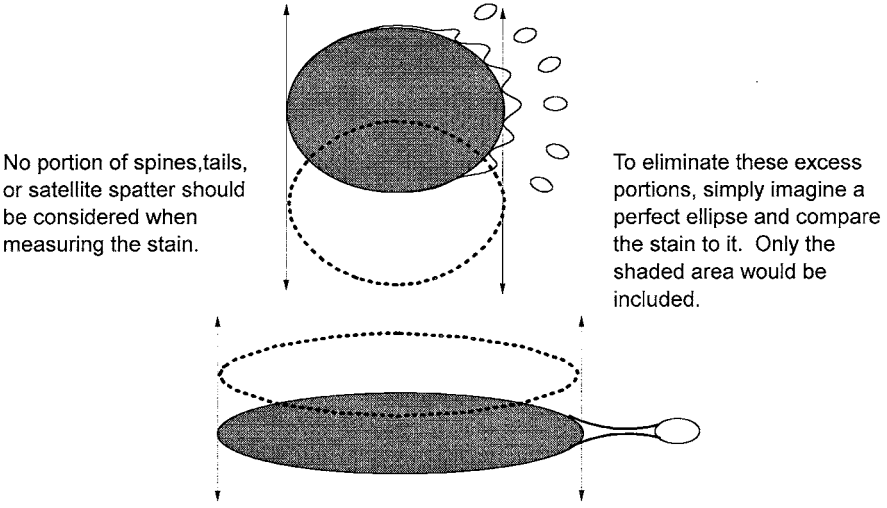

Figure 6.9 By comparing the stain to an imagined ellipse, one can generally distinguish those portions of the stain to disregard during the measurement process. Including scallops, spines, and satellite spatter in the measurement will result in a skewed estimate of the impact angle.

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. Figures 6.10 and 6.11 show examples of what portions of the stain the analyst should include and exclude. Although the tail structures will cloud only the length measurement, scallops may appear on the sides and end of the stain, making it more difficult to identify the true edges for both the length and width of the stain.

As discussed, closing out the ellipse by 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 (Figure 6.12) can help. 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 ellipse naturally closes. For example, Figure 6.13 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 6.14 shows a 10° template overlaying a 10° bloodstain; the two are nearly a perfect fit.

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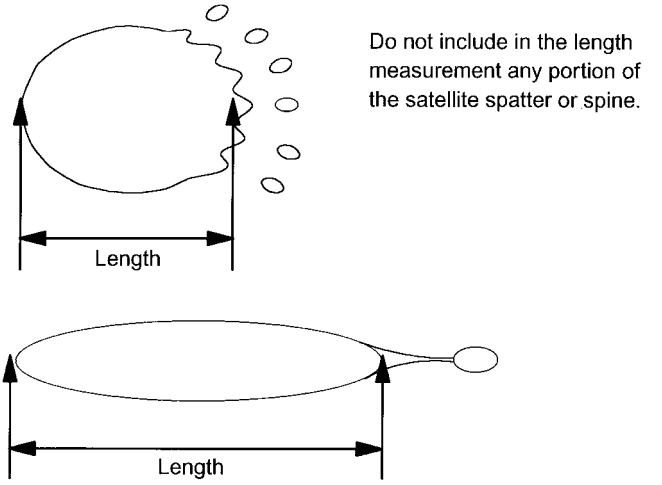

Figure 6.10 The length of the stain is measured along its major axis. The analyst must exclude from the measurement any portion of the spines, scallops, or satellite stains that may be present.

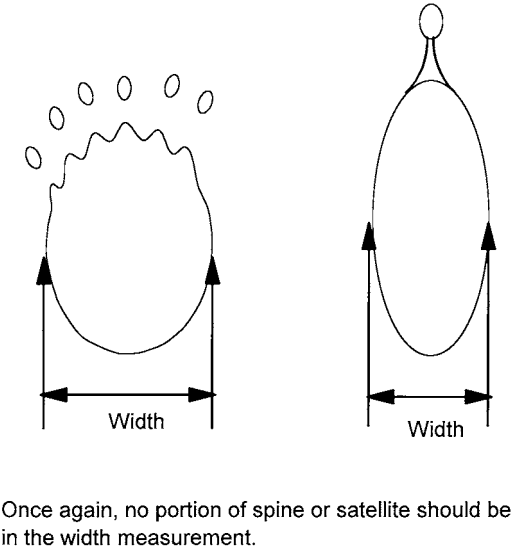

Figure 6.11 The width is measured along the minor axis of the stain. Although satellite spatter are less a concern when measuring this axis, scallops along the outer edges of the stain are often encountered. Do not include the scallop in the measurement.

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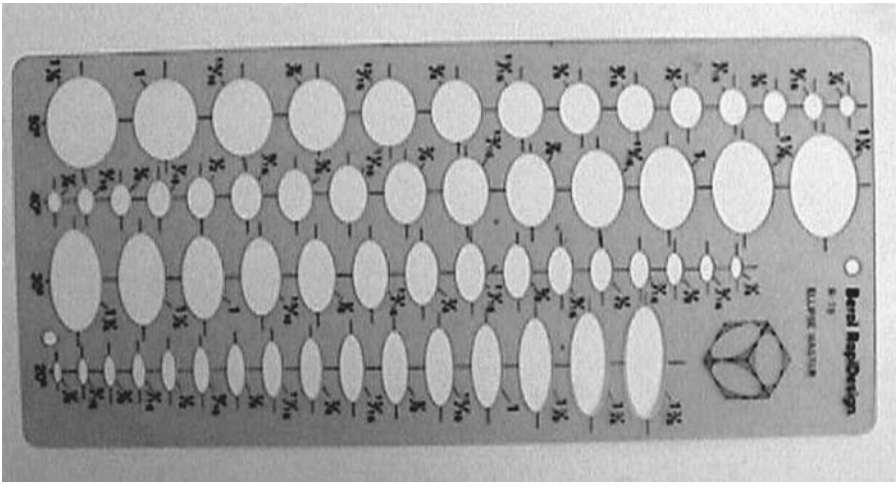

Figure 6.12 An ellipse template. Although not convenient for on-scene work, the comparison of the stain to an ellipse template in training and for practice helps the analyst recognize what portions of the stain to measure.

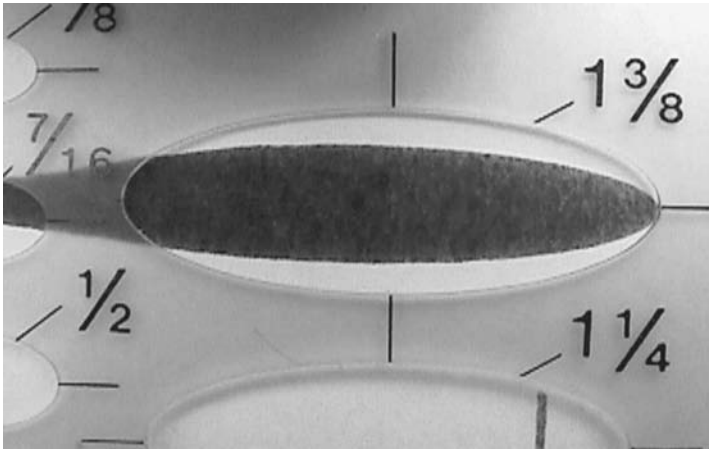

Figure 6.13 In this example, an ellipse of 20° overlays a stain with a 10° impact angle. The comparison makes it evident the two do not match.

As bloodstains vary in volume, they will also vary in size, even if they all impact at the same angle. In order for the ellipse template to be a functional means to measure bloodstains at the crime scene, analysts must have a set of ellipses not only for the varying degrees they require, but also to match the full range of bloodstains they may encounter. As a result, the template as a measuring mechanism is not feasible, because of cost and the problem of carrying the templates around. The template method, however,

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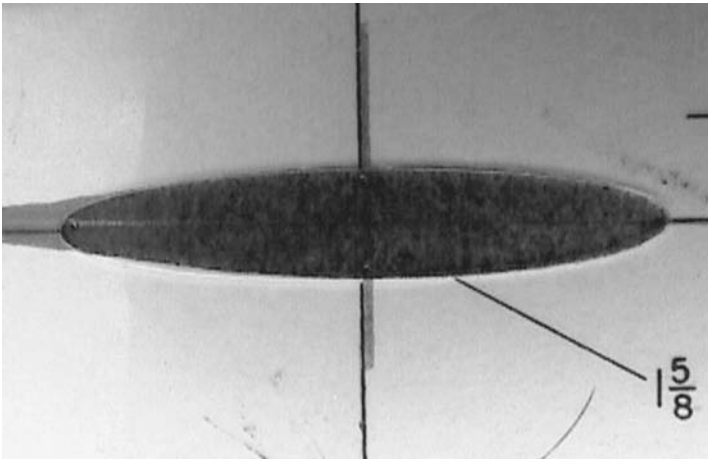

Figure 6.14 In this example, an ellipse of 10° overlays the same stain as shown in Figure 6.13. The fit is almost perfect. Note the left end of the ellipse; the stain's tail extends well past the perfect ellipse. The area of the stain extending beyond the ellipse should be ignored in the measurement of the stain.

is excellent in training situations. New analysts will find the template gives them a greater level of confidence in identifying the natural closing point of the stain.

The specific methods analysts use to measure stains are unimportant, as long as they are comfortable with both *what* they are measuring and the measuring device. Possible measuring devices include:

- A ruler or micrometer
- A drafting divider
- 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 0.5 mm. Any estimate below 0.5 mm would be subjective (Figure 6.15). The micrometer offers an additional advantage, because most are scaled to the level of 0.1 mm (Figures 6.16 and 6.17). 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 micrometer is much more functional.

The use of a photographer's loupe is also effective. However, the scale limitation previously discussed applies to this device as well. Loupes come in a variety of styles and configurations, and not all have a reticule, scale, or functional measuring mechanism (Figures 6.18 and 6.19). Before acquiring

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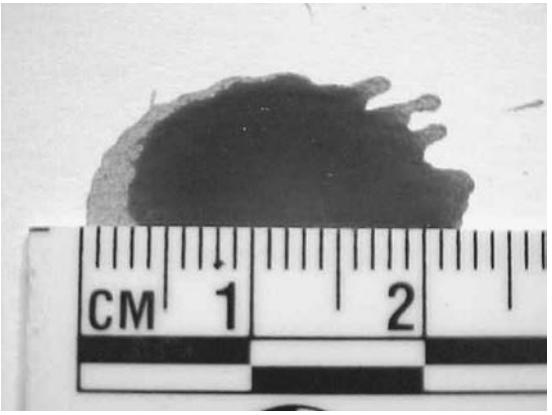

Figure 6.15 Measuring a stain with a simple ruler. The ruler is scaled only to 1 mm; thus the only estimate possible using this scale of reference is to the nearest 0.5 mm.

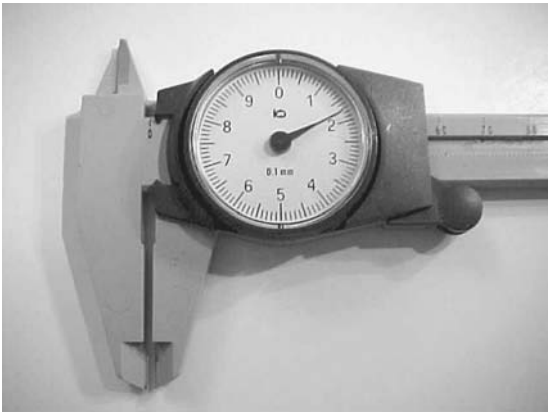

Figure 6.16 A micrometer. This device is scaled to the nearest 0.1 mm, allowing far more accurate measurement of the stain, particularly when viewing smaller stains.

one, the analyst should verify that there is a scale and that it is functional for the intended purpose.

The third method for measuring a bloodstain is with a drafting divider (Figure 6.20). The analyst adjusts the dividers to match what appears to be the widest part of the short axis (Figure 6.21). 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 (Figure 6.22). With the same adjustment, the procedure is followed from the opposite end of the stain.

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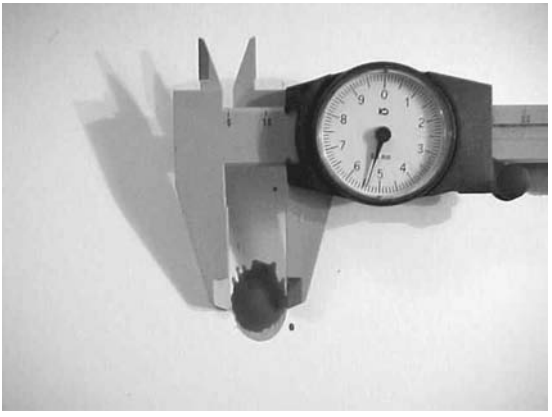

Figure 6.17 Comparison of the stain to the micrometer. The analyst matches the inside edge of the caliper to the stain edges and then reads the stain measurement using both the scaled bar (10 mm) and the needle gauge (5.4 mm). The short axis of this stain measures 15.4 mm.

Figure 6.18 A photographer's loupe used to measure a stain.

Once again, the point where the arms touch is marked (Figure 6.23). 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 ensure finding the widest point of the short axis.

To locate the long axis length, the analyst splits the difference between the two previously established marks (Figure 6.24). This third mark is the center of the long axis. The divider points are placed at the third central mark and at the top of the stain. This identifies a true half of the ellipse. By multiplying this measurement by two, the analyst finds the actual

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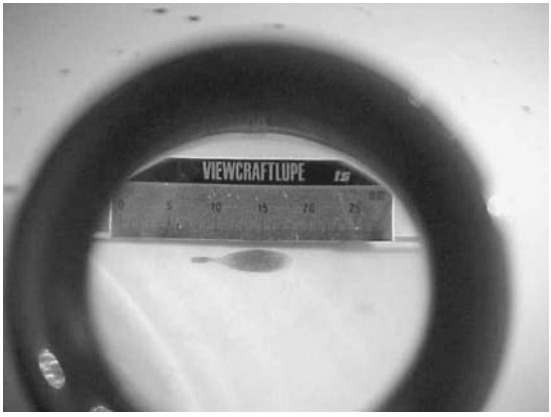

Figure 6.19 The view through the loupe. It is imperative to situate a functional scale of reference in the viewfinder in a manner that will allow easy comparison of the stain to the scale.

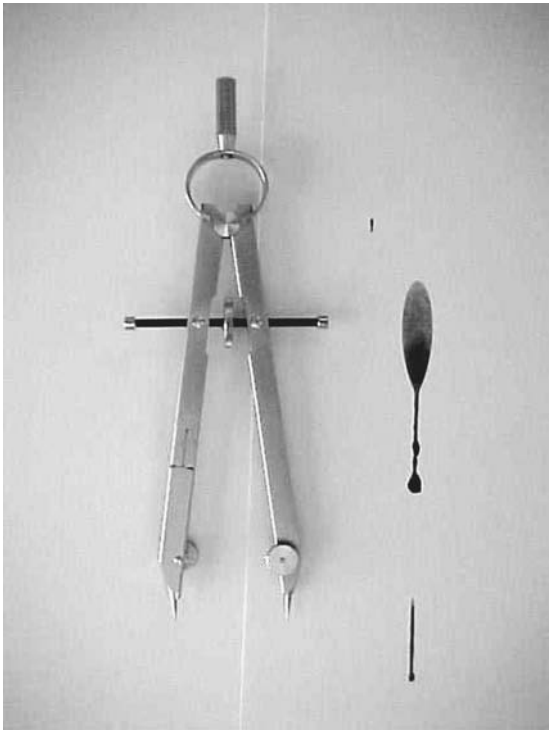

Figure 6.20 Use of a drafting divider to measure a stain. This method allows the analyst to effectively decide what portions of the stain to include or exclude in the measurement.

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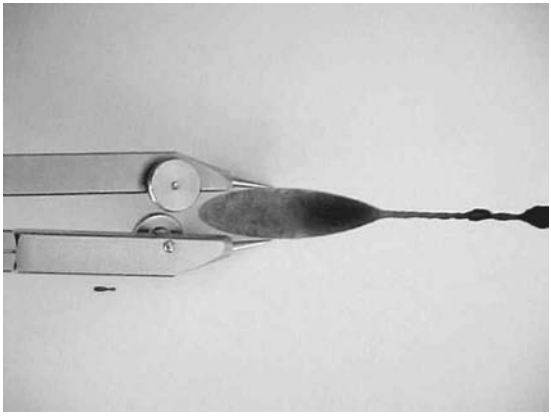

Figure 6.21 In the first step, match the divider points to the widest part of the outside edges.

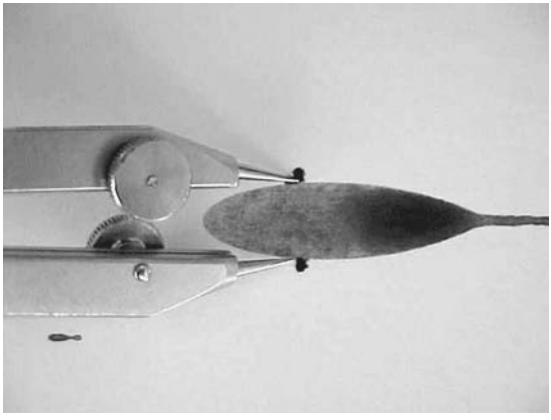

Figure 6.22 Without adjusting the arms, place them at the top (the leading edge of the stain) and move them down the body until the arms appear to touch the edge of the stain. Mark both points.

measurement of the long axis (Figure 6.25). 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 (Figure 6.26). 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 also Figure 6.27.) This method, as described, is very functional for teaching new analysts stain measurement.

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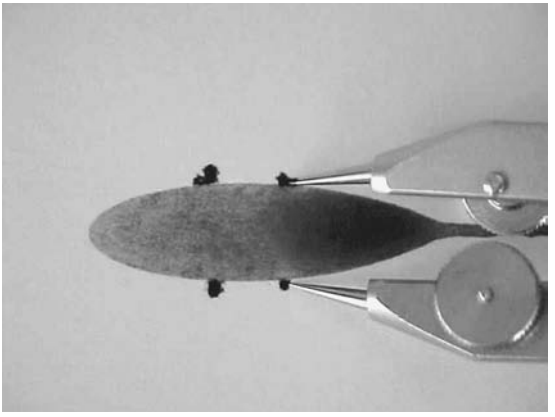

Figure 6.23 Without adjusting the arms, move them in the same fashion from the bottom of the stain (the edge with the tail and scallops) back toward the middle of the stain until the arms appear to touch the edge of the stain again. Mark these points.

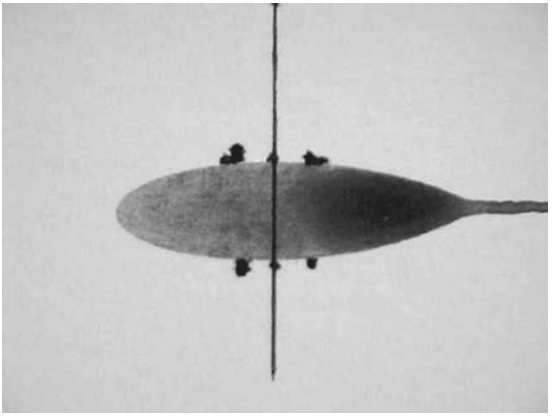

Figure 6.24 By splitting the difference of the measurement between the two marks we identify the widest part of the stain. This point often appears as an area when in fact it is really a point.

Determining Point of Origin Using Both Side and Overhead Views

Having learned how to determine the impact angle, let's combine the convergence point (the overhead view) and the impact angle (the side view) techniques. For the sake of simplicity, in the following example we will consider stains on a single surface, such as a floor.

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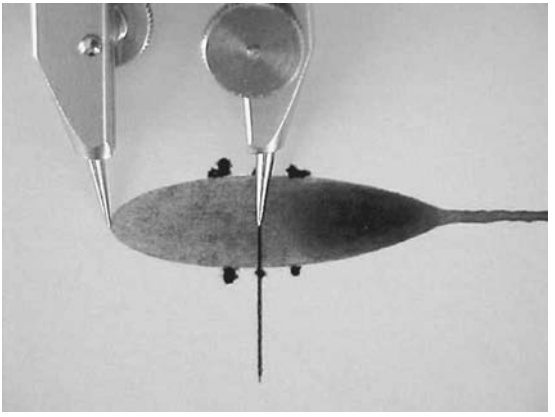

Figure 6.25 To locate the long axis length, place one arm on the center line and the other on the top (leading edge) of the stain. This measurement doubled identifies the length of the long axis.

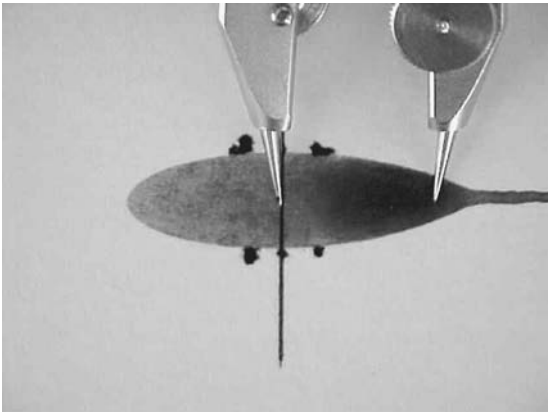

Figure 6.26 To visualize this point, without adjusting the arms and keeping the arm on the center point, simply rotate the other arm to the other end of the stain (the trailing edge).

Consider the three stains in Figure 6.28. Their flight paths appear to have a common convergence point in the scene. Assuming our three stains are "well-formed," the analyst measures each and applies the sine formula, identifying each stain's impact angle.

Although Figure 6.28 depicts elliptical stains, let us assume for the example that, based on the width-to-length ratios, the three stains impacted as follows:

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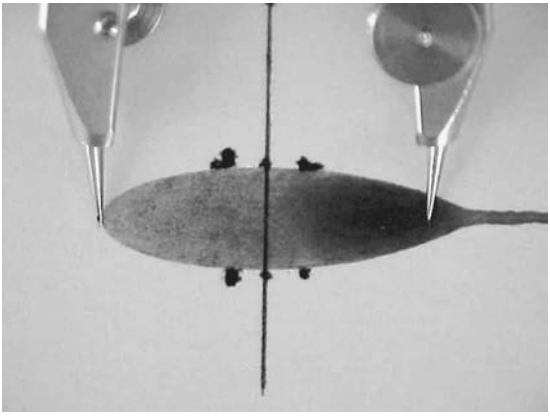

Figure 6.27 As with the ellipse template comparison method, note that there is an area on the trailing edge (where the tail and stain meet) that is not part of the actual parent stain and is not measured when measuring the stain length.

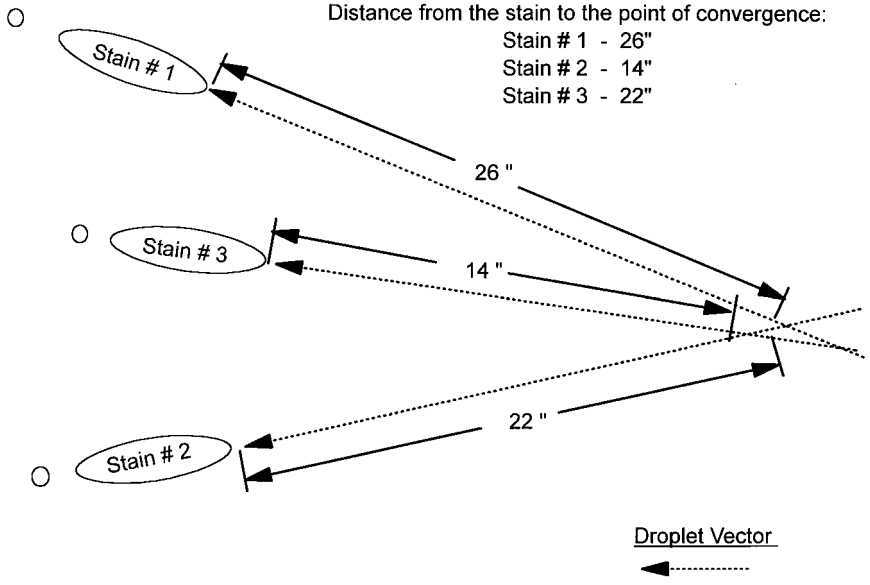

Figure 6.28 An example of using point of convergence evaluations. In this instance we have three stains with a common convergence point and we wish to determine if they share a common point of origin. We measure the distance from the base of each stain to the convergence point. We then combine that information with the impact angle in a graph (see Figure 6.29), which allows the analyst to visualize the point of origin for the spatter.

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- Stain #1, 30°
- Stain #2, 35°
- Stain #3, 46°

Imagine that the analyst then measured the distance from the convergence point to the rear edge of each stain and found:

- Stain #1 is 26 in. from the convergence
- Stain #2 is 22 in. from the convergence
- Stain #3 is 14 in. from the convergence

Graphing Points of Origin

One method of combining this impact angle and convergence point information is to use a graph. The analyst draws a graph with a positive X axis and 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, using whatever scale we choose.

The analyst begins by placing a mark for each stain along the X axis at the appropriate distance (e.g., 14 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 6.29. The point where the lines converge on the Z axis establishes the probable point 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 point of origin on the Z axis should become evident, assuming of course a true common origin exists. If the spatters evaluated are the result of two or more events that occurred at different heights, that too would become evident. Figure 6.30 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 an overhead perspective, one might believe they originated from a single event.

By considering the impact angles in conjunction with the overhead view for Figure 6.30, 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.

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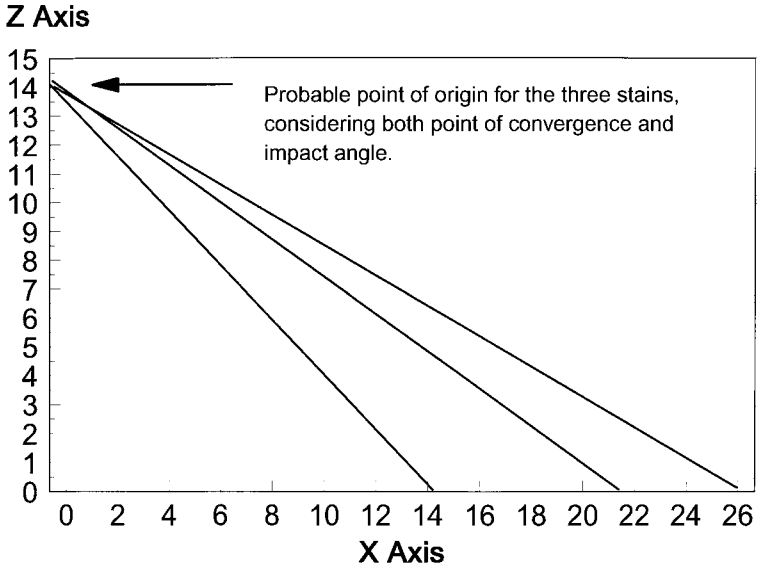

Figure 6.29 Graphing a point of origin. We mark the distance from the convergence point on the X axis and then draw a line to the Z axis at the indicated impact angle of each stain. Where the line crosses the Z axis is the probable point of origin (height above the target) for that particular stain. In this instance, the three stains appear to have a common point of origin about 14 to 15 in. above the target.

Defining Point of Origin with the Tangent Function

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. Figure 6.31 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.

To determine point of origin, the analyst uses the following formula:

$$\tan i = \mathrm{H/D} \tag{3}$$

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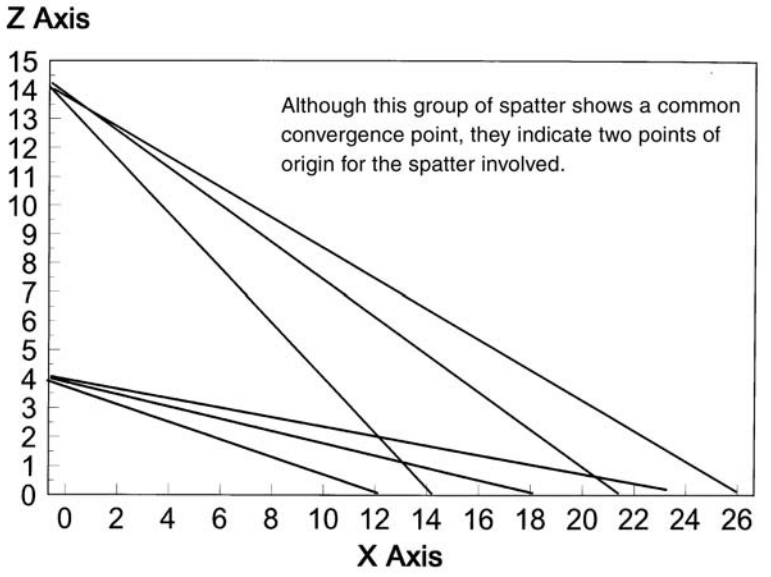
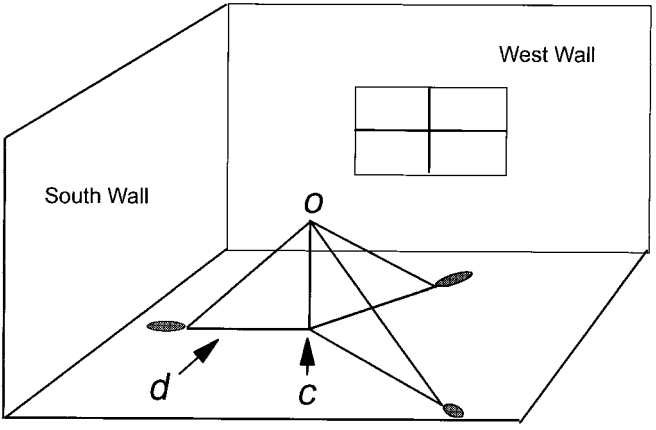


Figure 6.30 A graph indicating two points of origin. From an overhead view, all six stains would appear to share a common point of convergence. The inclusion of the impact angle information makes it apparent that two separate groups are present, indicating two separate events.



c = Point of convergence.
d = Distance from the base of the stain to the point of convergence.
o = Point of origin for the spatter.

Figure 6.31 The base of each stain's position, the point in two-dimensional space where their paths converge (c), and their point of origin (o) define a right triangle.

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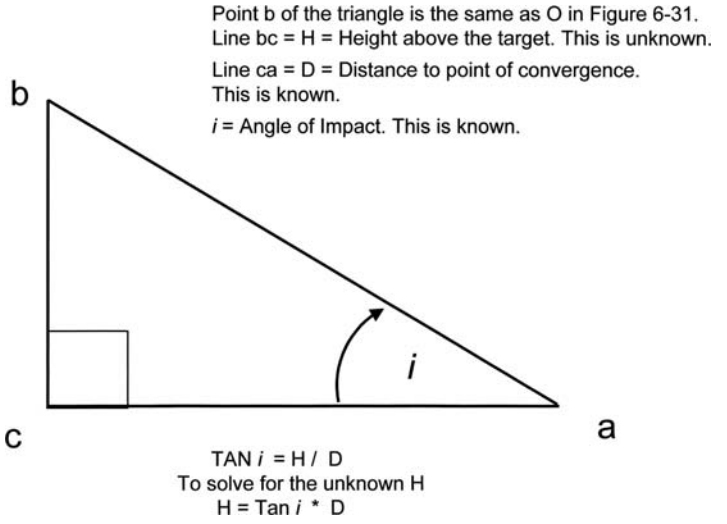

Figure 6.32 Our right triangle from Figure 6.31 further defined. We know the distance from the stain to the point of convergence (ca) and we can establish the impact angle (i). Using this information in the formula tan i = H/D, we simply balance the equation and solve for the unknown H. Thus H = tan i · D.

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 (Figure 6.32). For example:

$i = 19°$

D = 25 in.

tan 19 = .344

0.344 · 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.

Limitations in Point of Origin Evaluations

Using straight-line geometry and trigonometric functions, both the graph and tangent approach allow the analyst to identify the probable point of

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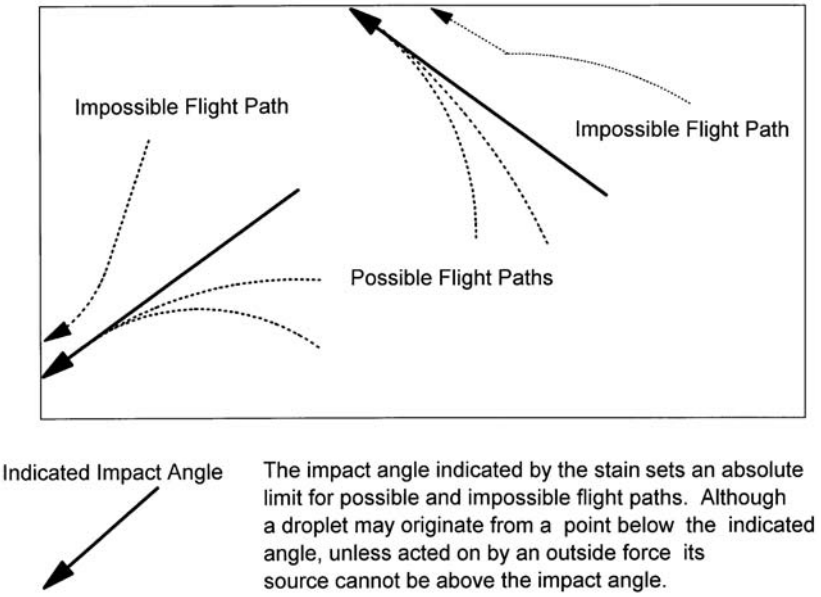

Figure 6.33 The angle of impact establishes an absolute limit for the droplet's origin. For instance, a droplet can originate at some point under the angle of impact. As it follows its path, gravity affects the path, making it steeper and causing the droplet to strike at the angle indicated by the stain. 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.

origin for our stains. Although generally accurate, it should be evident to the reader that both methods make a major assumption. Both assume the droplets involved travel in straight-line trajectories. Unfortunately this isn't true, because both gravity and air resistance affect the droplet, creating distinct arched parabolas.

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 path absolutely. They do, however, place specific limits on that path. Consider Figure 6.33. The impact angle for each droplet in effect sets a limit 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 point behind the indicated angle of impact. That is, it may have been projected out toward the wall at 80°. As the droplet slows in flight its parabola angles downward to the ground, eventually striking the target at the indicated 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°). Obviously, this effect is relative to the plane of the target.

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What this limitation tells us is that we must always use caution in considering the results of the point of origin evaluations. This is particularly true for those situations involving dual impacts, like those expressed in Figure 6.33. The indicated point of origin sets an absolute upper limit for the event, but cannot always exclude the event from having occurred at a point beneath the indicated point of origin. The ability to make such an exclusion is situation driven, depending on the number of stains available and the nature and dispersion of the stains.

Three-Dimensional Evaluations of Point of Origin

A final manner of evaluating point of origin is in a graphic three-dimensional fashion. This is possible both in a physical sense, using the "stringing" technique, or by using computer-aided analysis tools.

Stringing Scenes

For many years stringing was a basic method taught to bloodstain analysts, but its place in on-scene analysis is slipping into the past. It is still useful, however, as a visual aid to help explain "point of origin" to both juries and students (Figure 6.34). The true origin of stringing is somewhat in question.[5] Herb MacDonell was the first to describe the process itself, yet we usually credit Balthazard et al. for developing the foundation of stringing.

The stringing process is simply a physical extension of what we've 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 reader may wish to refer back to Chapter 5 for a discussion of droplet directionality.) The string is then extended back along the indicated path and angle. The point in space where the strings from several stains produce a generalized convergence point indicates the probable point of origin.

Stringing as a technique has several drawbacks that explain 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 is difficult at best.

The use of a laser protractor can eliminate some of the problems associated with actual strings (Figure 6.35). The commercially available

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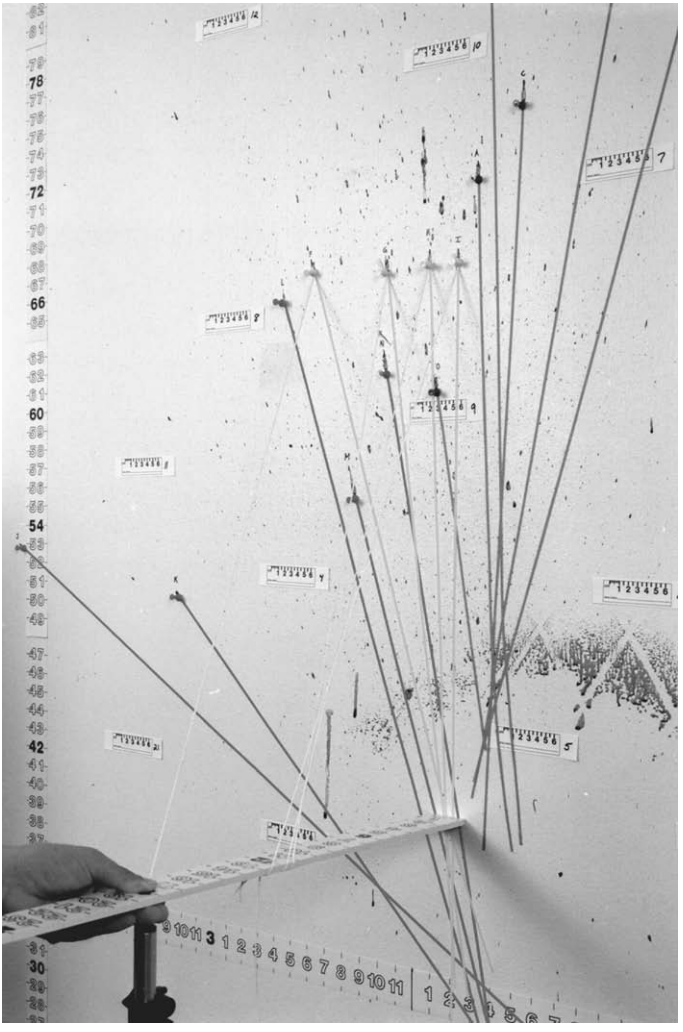

Figure 6.34 An example of on-scene stringing in combination with the use of graphic tape. The graphic tape demonstrates the point of convergence, and the strings demonstrate the point of origin. (Photograph courtesy of Toby Wolson, Miami-Dade Police Department, Florida.)

protractor is placed on the stain, as described. The laser is turned on and the point where the laser strikes a nearby surface is marked. A string is then attached to the stain and this point. This process is repeated for each stain evaluated. Not only does the laser protractor make the "stringing" more precise, it also reduces the level of labor necessary to string a scene.

When you review the results of a stringing, it should raise an immdiate red flag if the analyst "pinpoints" a position using more than three or four stains. The likelihood of obtaining a pinpoint position with strings is low to

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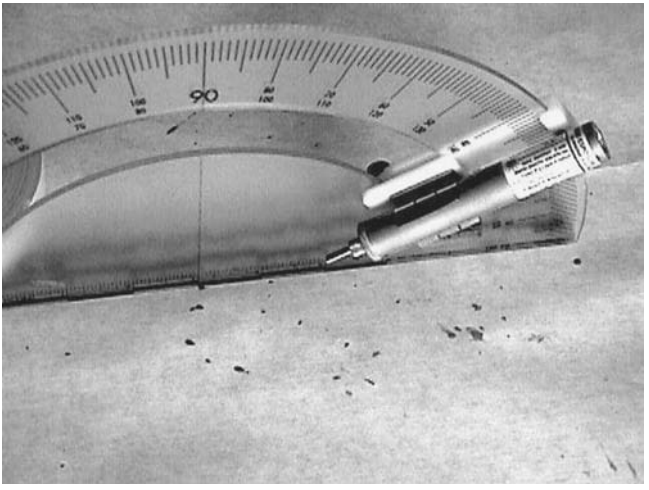

Figure 6.35 A laser protractor. This device assists the analyst in placing strings in the scene far more accurately and efficiently.

begin with. As we increase the number of stains and strings considered, that possibility decreases dramatically.

Forensic Software Applications

Computer software advancements over the past 10 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 point of origin information. A program called *Trajectories* was one of the first true "analysis" programs. Developed in 1987 by Dr. Alfred Carter of Carleton University, it allowed the analyst to evaluate point 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 allows for point of origin calculations on vertical surfaces. *BackTrack*® employs actual flight path (parabola) calculations, which incorporate estimates of blood droplet volume and gravity and air resistance factors.

Shortly after *BackTrack*®*'s* release, FCO released another program, *BackTrack/Strings*®. FCO scaled down this version somewhat, changing the manner in which it handles the point of origin algorithm. It has all the primary functions of *BackTrack*®, but utilizes a strings approach in lieu of the parabola approach to determine flight paths.

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 glancing angle (a term synonymous with directional

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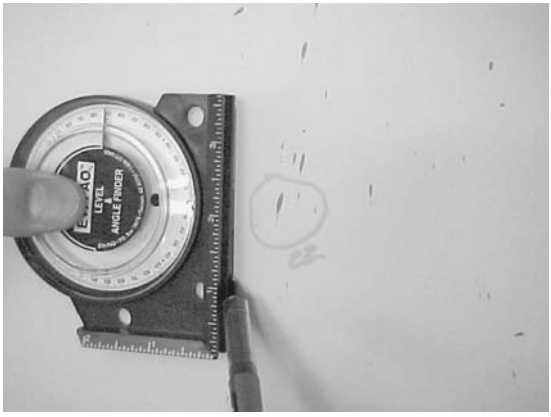

Figure 6.36 Using forensic software such as *Backtrack Images®*, the analyst must input on-scene information. In this photograph the analyst draws a plumb line adjacent to the stain, prior to taking the photograph, which *Backtrack Images®* will analyze. The plumb line helps the software identify the gamma (directional) angle of the stain.

angle). Once these are 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 (an overhead 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 these convergence points are chosen, the analyst saves them and the software creates a graphical representation of the probable point of origin.

Subsequent to *Backtrack®*, Dr. Carter produced two additional programs that work in conjunction with each other. The first was *Backtrack Images®*, which takes bitmap photographs of stains and allows the analyst to identify the gamma and impact angle. To use *Backtrack 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 *Backtrack Images®* can establish a gamma angle (Figure 6.36). The analyst then places a small, readable reference scale, which *Backtrack Images®* will use to determine actual scale of the photograph (Figure 6.37). In addition, 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 millimeter scales by each, and then draws the plumb line. Then the

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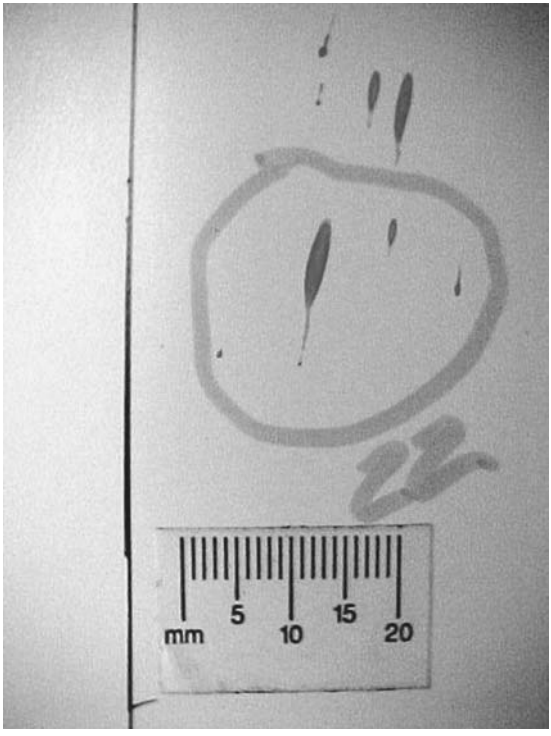

Figure 6.37 A small scale is included as well, to allow the software to accurately place the stain in the scene and establish its measurements. Note that the stain is marked (e.g., Stain #22) so each photo is easily distinguished from all others.

photos are taken. Even with a large pattern, where the number of stains chosen for evaluation may exceed 20, the entire process can be accomplished on scene in under a half hour.

The *Backtrack Images*® methodology allows the analyst to compare the stain 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 figures the angle from the ellipse measurements. All of the information derived for each stain is then stored in a database, that both *Backtrack Images*® and *Backtrack/Win*® can use and manipulate.

The second program, *Backtrack/Win*®, takes input either from *Backtrack Images*® or from information gathered by the analyst. Following a similar routine as in previous *Backtrack*® products, it determines the point of convergence and point of origin and creates printouts demonstrating this information. Figure 6.38 is a printout of an overhead view created by *Backtrack/Win*®. The small cross represents the established convergence point for the overhead view. Figure 6.39 is a side-view printout of the same stain pattern. Once again the small cross represents the side-view convergence point, and with both

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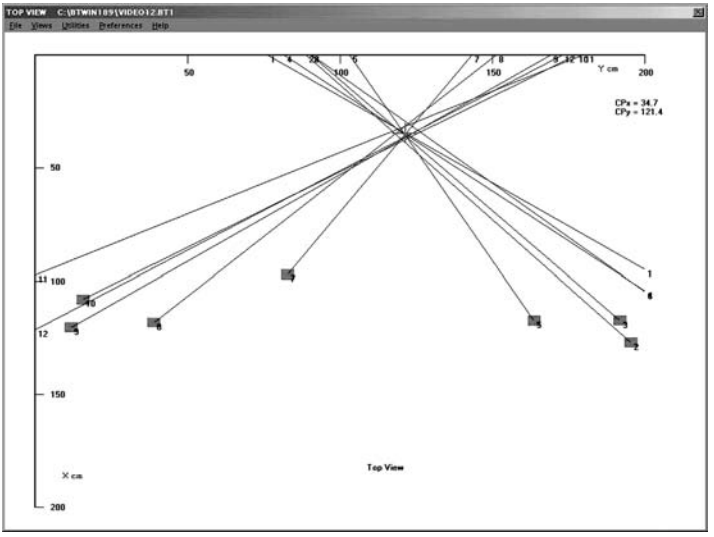

Figure 6.38 A *Backtrack/Win*® overhead view screen. This view identifies the point of convergence for a group of spatter stains. The small cross is the mathematical mean for all the points of convergence. Its location is shown in text in the upper right of the screen.

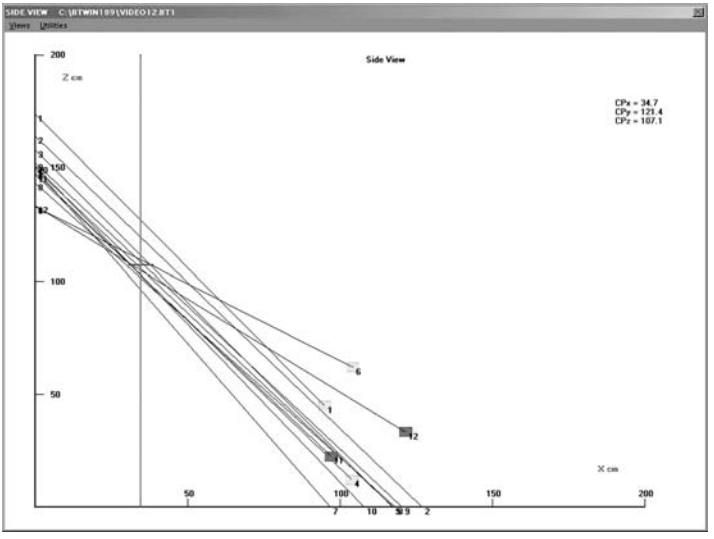

Figure 6.39 A side-view screen from *Backtrack/Win*®. In this view the small cross identifies the point of origin for the spatter. Its location is shown in text in the upper right of the screen.

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convergence calculations complete, the display textually lists the point of origin in the upper right corner.

Automation Efficiency or Precision — An Important Distinction

We hope it is evident that forensic software programs allow the analyst to more efficiently locate the point 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 point of origin. The authors would argue that it does not.

In a classic stringing technique, one usually limits the point of origin to a 10- or 12-in. area in which the strings appear to cross each other. 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 doesn't matter because the nature 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 be only 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. In addition, 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 a point 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 point 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.

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Summary

Having defined the point at which a group of stains converge or from which they originate, how does the analyst use this information? Because we lack specific knowledge of the crime, this process helps identify the general location at which some type of blow or 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 blow or impact that was not otherwise evident.

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 point of origin, let us assume we find evidence of blows delivered from a point low on the ground. Thus, we have physical proof with which to refute, at least in part, the subject's statement.

Point 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, better defines the point or area in space from which the droplets originated.

In the past, we generally used the stringing or graphing methods to identify this point. Recent 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 point of origin estimation is exactly that — *an estimation*.

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5. MacDonell, Herbert L., Balthazard Was Great but He Didn't String Us Along, *Int. Assoc. of Bloodstain Pattern Analysts News,* Volume 11, Number 1, March 1995, p. 10.

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Evaluating Impact Spatter Bloodstains

7

One of the primary functions of the analyst is to define or categorize the specific stains and patterns found. Once these are 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 spatter pattern. As defined in Chapter 3, spatter is a stain resulting from some application of force or energy to a blood source. As definitive as this is, unfortunately there is little agreement on how to differentiate spatter. What is generally agreed is that spatter patterns often help us identify the nature of the force involved in the event.

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. Analysts base one approach to categorizing spatter on impact velocities. As a result of early references in bloodstain analysis, bloodstains routinely became categorized into three velocity groupings — low, medium, and high.[1] These categories refer to the nature of the impact or force causing the stain. 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 energy applied to the blood precludes the drop from breaking up. Such stains are not true spatter and generally are at least 4 mm in diameter. Low-velocity stains are said 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

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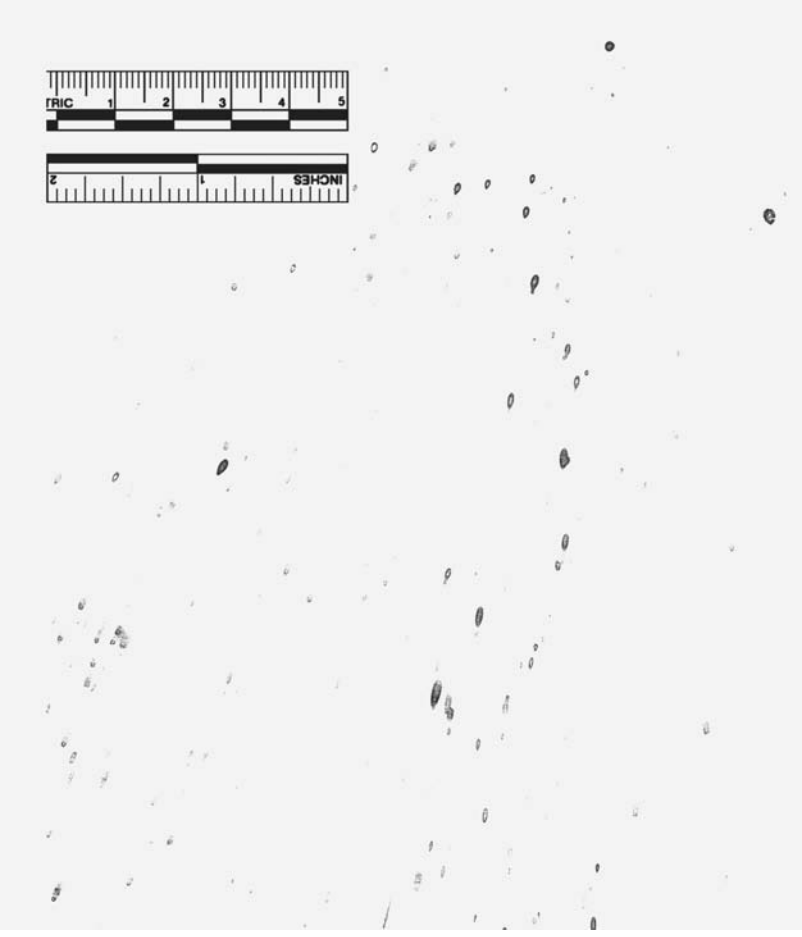

Figure 7.1 An example of a stain meeting the medium velocity definition. This pattern was produced by a blunt force impact to a blood source.

subsequently falls to the floor. The category of low-velocity stains now includes many different types of stains. Generally, analysts include any non-spatter stain in this classification. As a result, the category is so broad it does little to define the specific character of the stain in question.

Medium-velocity spatter are patterns with a preponderant stain size of generally 1 to 4 mm in diameter, created as a result of some application of force.[2] Historically, they are considered the result of forces or energy of up to 25 ft/s. The spatter is smaller than that found in low-velocity stains and results from the increase in the energy applied to the event. Figures 7.1 and 7.2 depict two medium-velocity spatter patterns.

High-velocity spatter is a pattern in which the preponderant stain size is 1 mm or less in diameter. These stains are generally associated with a force

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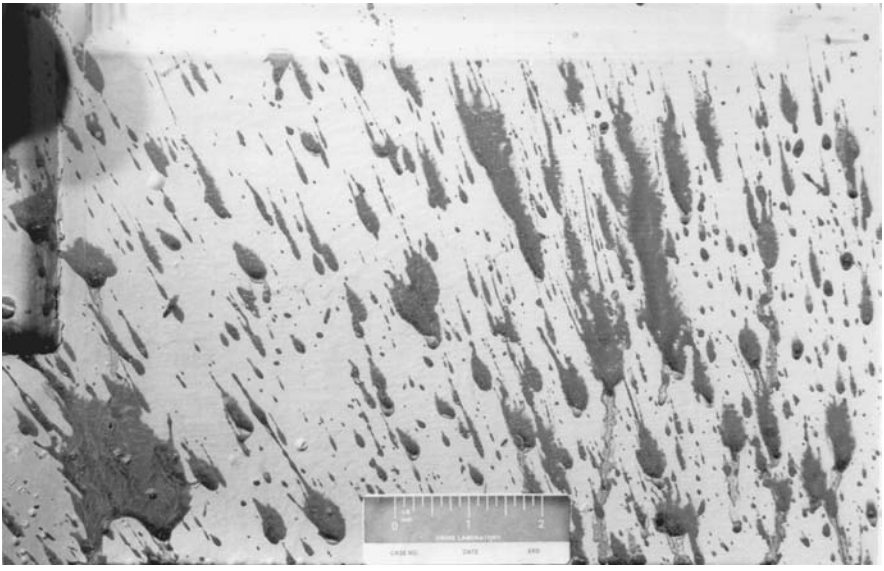

Figure 7.2 A case example of impact spatter meeting the medium velocity definition. These stains resulted from a blunt force beating to the victim. The stains were then altered somewhat by a fire set to conceal the crime. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, Oregon.)

or energy in excess of 100 ft/s.[3] They are often described as mist-like (Figure 7.3).

The problem with the "velocity" method of description is most evident when analysts discuss stains. Quite often when using a velocity label as a description, others assume it to mean a definition of the event. That is, because something is classified as a high-velocity incident, others believe the analyst means the underlying event must be a gunshot.

Besides assigning event status to the stain, many analysts also tend to set absolute ranges for the so-called low-, medium-, and high-velocity spatter patterns. Analysts generally quote the work of MacDonell and Bialousz as a basis for such ranges.* In fact, there 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 they did not intend to assign event status to "medium velocity" or "high velocity" labels, but as a result of their work analysts often make such associations. For instance, we generally associate medium-velocity spatter with blunt trauma events, but these patterns are not in and of themselves defined as being *only* the result of such events. Mac-

* The authors as well as others are guilty of this practice.[4,5]

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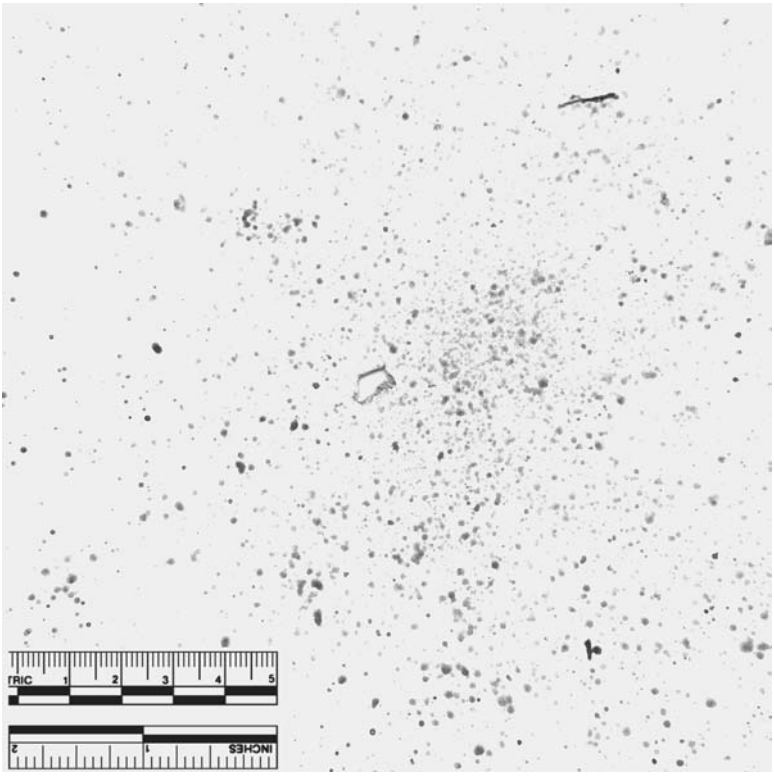

Figure 7.3 An example of a stain meeting the high-velocity definition. This pattern was produced by a .22 caliber gunshot through a bloody sponge.

Donell and Bialousz simply provided a basic method of definition or description for spatter patterns and associated certain events with the patterns.

What remains evident in their work is the correlation that as we increase the amount of energy applied to the blood source, we see a corresponding decrease in spatter size. It is this particular characteristic that often allows us to differentiate the spatter of one event from another.

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), not to the velocity of the blood in flight. Confusion often surrounds this issue.

Contrasting with the velocity label approach is the descriptive label. As a result 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, whereas coarse spatter were those

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stains with diameters of greater than 3 mm.[7] The approach was not radically different from MacDonell's; it simply didn't consider the underlying event.

Another advocate of a descriptive approach is Judy Bunker. Bunker did not adopt Parker's terminology, but she teaches 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 is that the analyst first observe the stain and make conclusions about it later.[8] This method also eliminates some disparity evident with velocity labeling as we use it today.

For instance, there is a category of pattern typically associated with low velocity in which the force fails to meet the criteria of the associated category. The pattern involved is the spatter caused when blood simply drips into liquid blood. We know, based on experimentation by MacDonell, that the terminal velocity of blood appears to be about 25 ft/s.[9] Other work in the area of fluid dynamics certainly supports MacDonell's figure.[10] Based on terminal velocity, we know the force active in creating satellite spatter when drops simply fall cannot be higher. The satellite stains found around a pool of blood result singularly from this application of gravity and the shifts it causes in the mass of the blood drop. Nevertheless, satellite stains in these patterns usually range between 1.5 and 2 mm in diameter, so in this instance we have a clear example of spatter from a "low"-velocity incident that meets the "medium"-velocity range criteria. This begs the question, should we relabel our definition of what gravitational forces are or simply associate the stain group with the medium-velocity category?

It is not the intent of the authors to attack the velocity description; the approach simply has limitations. When used to describe and categorize spatter of specific sizes it works well in most instances. Its limitations come from assigning absolute demarcation points (e.g., 5 to 25 ft/s) for which known exceptions exist, associating the label to specific events to the exclusion of others, and the broad categories it establishes.

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. Medium-velocity or coarse spatter is 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. Although not common to most crime scenes, examples of high-velocity spatter are also found in circumstances involving explosive force (Figure 7.4). The reader should consider these statements as a general guideline and nothing more.

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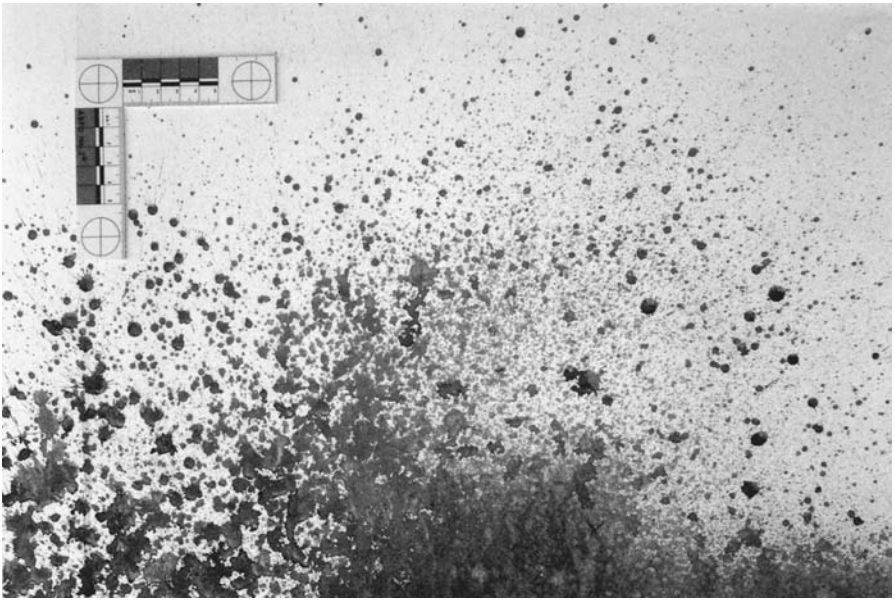

Figure 7.4 The pattern produced when a flash-bang device was activated next to a small pool of blood. The target was in a vertical position. (Photograph courtesy of Tom J. Griffin.)

Understanding the Concept of Preponderant Stain Size

Whether using the velocity label or the descriptive label, at some point the analyst must evaluate the given impact pattern and categorize it. As discussed, we generally categorize a pattern by looking at the size of the stains present in the pattern. 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	Number 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 present (e.g., 0.25 mm) the pattern might be categorized as 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 low velocity.

To properly categorize a pattern, the analyst looks at the preponderant stain size within it. In this instance that happens to be the 1.1–4 mm size

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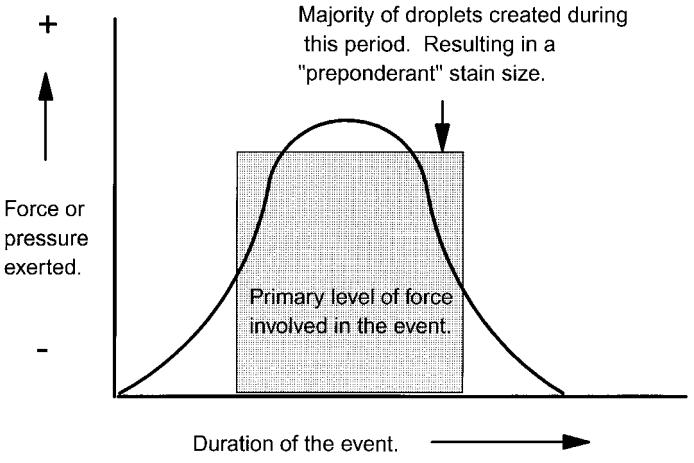

Figure 7.5 The shadowed box represents the level of force most evident in the event. The predominant spatter present in the pattern will result from this level of force, but as the force builds, peaks, and then wanes, other spatter of varying sizes will be produced as well. Thus, in any spatter pattern smaller and larger spatter will likely be present.

(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 don't exist. There are no perfect patterns. The size range evident in any pattern is often great. There simply are no absolute demarcations within the pattern that will correlate to either our velocity or descriptive label.

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, and 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 (Figure 7.5).

Droplets created when the force is at its predominant level (the shadowed area of Figure 7.5) 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 spatter much smaller than our preponderant stain size created when the force was at its absolute peak.

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The analyst must decide which size of stain is the preponderant stain in the pattern. Analysts most often 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 spatter.

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 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 the analyst. The two patterns (the scene pattern and slap-drop standard), when evaluated using only 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 (Figure 7.6).

This example demonstrates some of the difficulties encountered when categorizing spatter patterns. The slap pattern was not consistent with the questioned pattern, yet based on a limited eyeball examination it appeared to be consistent. Additionally, the categorization of a stain as medium velocity, 86% of which is under 1 mm in size, fails to consider either the whole pattern concept or rewrites the underlying definition. Such contradictory issues are probably more common than we might imagine. They demand we carefully consider what specific characteristics lead us to our spatter pattern conclusions.

This is not to say that analysts must measure each and every stain to make a call on a pattern, but they must ensure the sampling used for categorization is sufficient. Once again, we would prefer the decision to include or exclude a pattern as being consistent with something be based on a clear, specific, and verifiable characteristic.

* An event in which a small volume of blood was slapped by several fingers.

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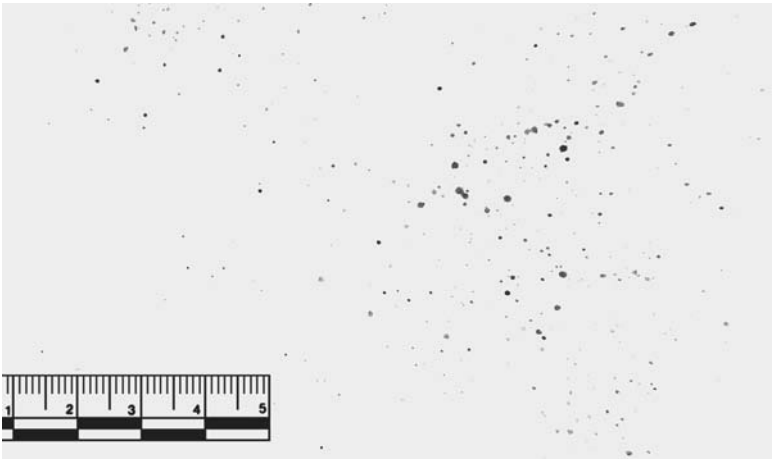

Figure 7.6 An example of the difficulty present in the velocity label description. This spatter resulted from a slap to a small volume of blood, which we would generally define as blunt force. It produces, however, a fine spatter that is well within the parameters of the high velocity definition. Velocity definitions should always be attributed to the pattern based on stain characteristics — not on the event.

Distinguishing Spatter from Contact Stains

Given the discussion in Chapter 4 of blood's adhesive quality, 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 may claim incidental contact transfers as the source of stains found on their clothing.

In some situations it is possible for light contact of a bloody object to mimic or appear to be a spatter stain. If possible, the analyst must distinguish between spatter created by violent dynamic events and stains created by mere incidental contact. When found as a whole pattern or large stain, the differences between the two are easy to distinguish. Often, however, these stains are quite small and their true source may not be immediately evident. But even when presented with limited staining, the analyst can often make this distinction. This is particularly true when the stain is on fabric. Remember, the two stains result from distinctly different actions. One is projected onto the target, whereas the other 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. Because the stain is generally the result of a wipe or swipe (with lateral motion), the deeper areas

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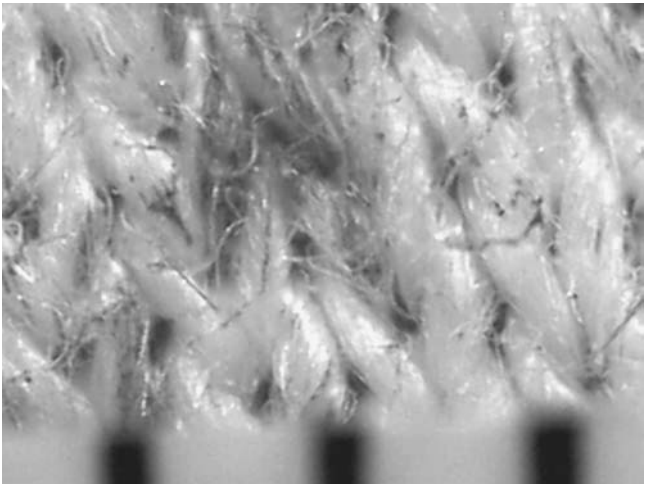

Figure 7.7 An example of a swipe mark on fabric viewed under 60× magnification. Note the discoloration from staining is present on the upper surfaces of the weave.

of the weave are often left untouched by the blood source. Even in situations in which there is a compression contact, areas within the weave may still be free of blood. Figure 7.7 demonstrates this appearance as viewed under 60× magnification on 50/50 cotton/polyester material.

On the other hand, when spatter strikes clothing it does so in a projected fashion. The small droplets impact into the weave, rather than brushing against it. In a spatter stain, the lower levels of the weave are likely to exhibit staining. Figure 7.8 demonstrates two projected spatter stains on 50/50 cotton/polyester material. Note the distinct differences between the stains in Figures 7.7 and 7.8. Pex and Vaughan found this type of examination particularly useful in situations involving gunshots.[11] 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.

In this type of examination, some level of discrimination by the analyst is usually possible. This allows the analyst to distinguish projected spatter stains from those caused by contact. 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. This concern is still true today, because the analyst can often corroborate or disprove statements of such individuals using the bloodstains present on their clothing.

Figure 7.9 is an interesting example of a stain that appeared at first glance to be related to a spatter event. The stain certainly gives the appearance of meeting the "high velocity" definition and looks to be spatter. The stain was

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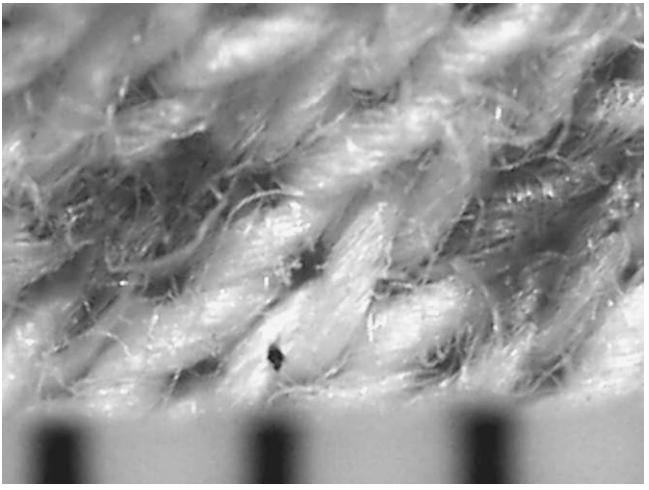

Figure 7.8 An example of spatter viewed at 60× magnification. The blood was projected onto the target and penetrates deeply into the weave. In comparison to a stain similar to that in Figure 7.7, it is easy to distinguish between them.

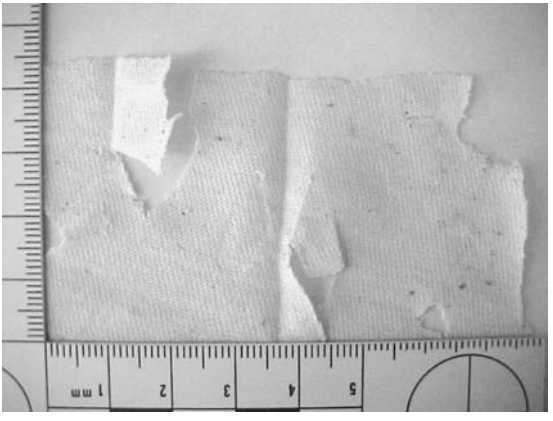

Figure 7.9 A stain on a piece of cotton t-shirt that upon initial evaluation was considered to be spatter. The t-shirt was recovered from a man who was suspected of killing another person with a shotgun.

recovered from the right lower chest area of the t-shirt taken from a suspect in a shooting (Figure 7.10). The victim was shot once in the head. Upon examination using proper lighting and magnification, the stain was clearly not related to a spatter event (Figure 7.11). The stain consisted of coagulated material. Subsequent DNA analysis revealed that 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

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Figure 7.10 The t-shirt from which the spatter was recovered. The large circled area is where the stain was cut out of the fabric. No other spatter or staining was present on the shirt.

for the stain, what was evident from examination was that the stain did not result from spatter created as a result of the gunshot.

Impact Droplet Size

As discussed up to this point, 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. 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 have discovered, blood and blood droplets do not spontaneously degenerate from one volume to another. It is the energy transferred by the impact to the mass of blood that causes the blood source to break up into droplets. This is also true of droplets in free flight. To further divide and become smaller droplets, some force must act on them. The oscillations this force creates within the mass of blood may

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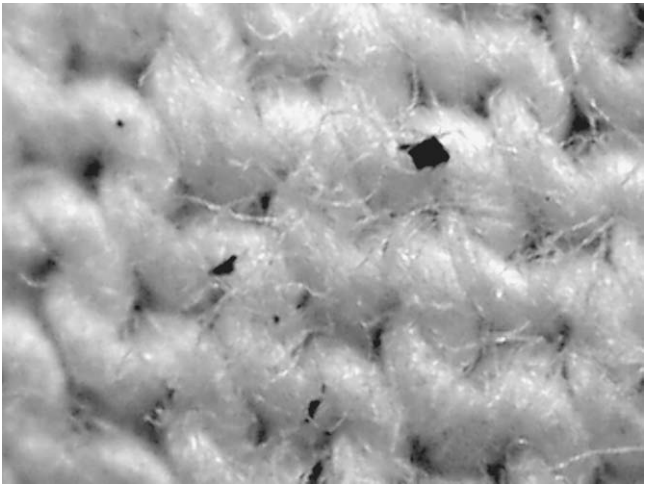

Figure 7.11 The t-shirt "spatter" viewed under 60× magnification. The stains were clearly the result of some event that occurred after the blood coagulated. DNA analysis added another wrinkle to the initial evaluation. The stains were the product of two DNA sources — the primary source was the owner of the t-shirt, and the secondary source was the victim. Whatever the actual method of creation, these stains were not the result of the spattering of fresh blood.

overcome the cohesive forces (e.g., surface tension, viscosity) working to hold the original structure intact. Once blood is set in motion by an impact, no spontaneous subdivision will occur because 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, droplets resulting from impacts are significantly smaller than those resulting from drips and similar actions. We have found impact droplet diameters of 2 mm and smaller.[13] Remember, these are the actual droplets in flight, not the resulting stains. Droplets of this size have volumes of 5 μl or less.

This issue of the droplet's size is significant in our consideration of impact spatter, for one reason. As we examined in Chapter 4, the smaller the droplet, the more quickly, 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 point where the impact occurred appear 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 droplets in flight is not distinctly affected by other extraneous forces (e.g., wind or air currents), and they travel as near-perfect spheres.

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Figure 7.12 An example of the radiating effect observed in spatter patterns. The origin of the spatter is a point about 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, Alaska.)

Pattern Configuration and Dispersion in Impacts

Patterns associated with impact spatter as a general rule have a radiating effect (Figure 7.12). The center of this radiating pattern, as one would imagine, is the point where the impact occurred to the blood source. How the pattern and individual stains within the pattern manifest themselves depends on the relationship of the target 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 7.13 provides a basic understanding of this relationship. Refer to Chapter 4 for a discussion on how angle on 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 per square inch. As the droplets travel outward from the impact site, the distance between the stains increases as they follow their individual paths.

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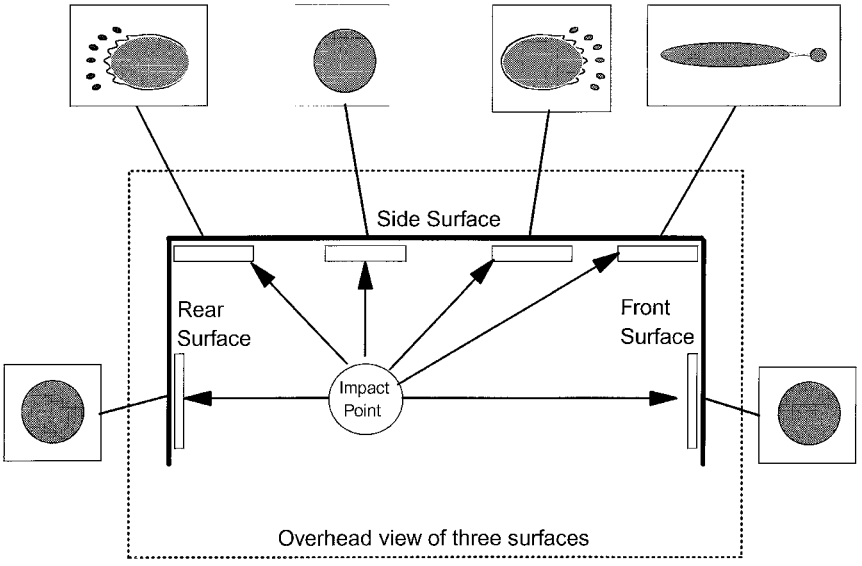

Figure 7.13 Stain shape and the relationship of the target to the impact. The stains we find in any given event may exist on any number of target surfaces. Thus the position of the target in relation to the impact point will produce any number of different impact angles. By considering the resulting stain shapes, the stain positions, and the overall pattern configuration, we can distinguish the probable impact point.

This is best understood if we limit our discussion to stains in a single dimension. Using Figure 7.14, imagine an impact creating droplets. These droplets travel along a single plane, as represented in the figure. Because of this 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. Figures 7.15 and 7.16 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 7.15) shows a level of dispersion lower than that evident in the distant target (Figure 7.16).

Of course, 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 7.17, 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 along the same initial path. Because of their size, they followed distinctly different parabolas. Smaller droplets simply do not carry as far as larger droplets. This issue is

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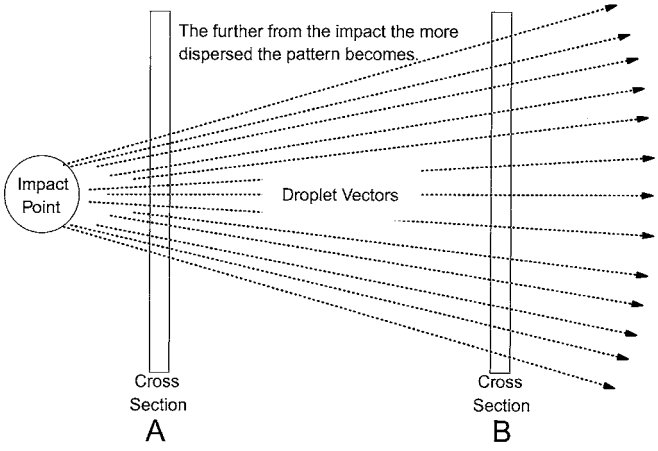

Figure 7.14 The radiating effect of a spatter pattern results in a higher level of dispersion in the stains farthest from the impact point. The figure is idealized and does not consider the effects of air resistance and/or individual droplet parabolas. These factors also play a role in the apparent dispersion present in a pattern.

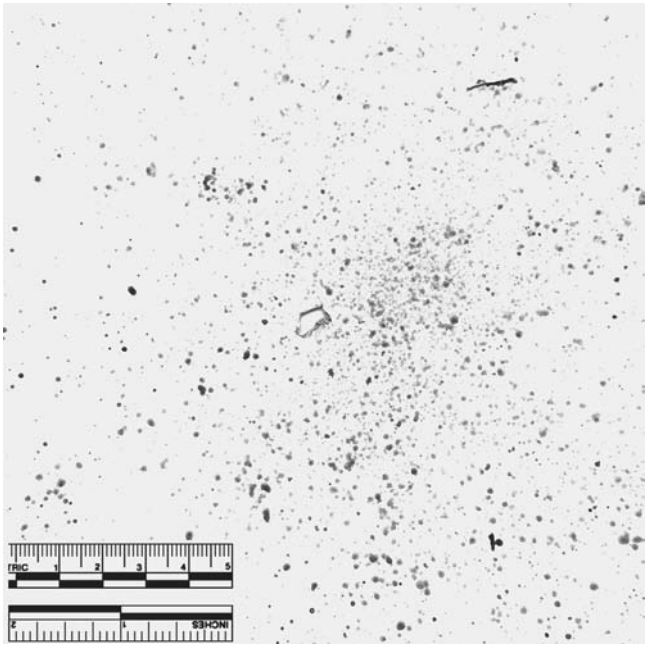

Figure 7.15 This pattern shows the level of dispersion in a gunshot event when the target was 6 in. from the blood source. Note the misting effect and the high number of stains present in the central area of the pattern. Compare this to the dispersion in Figure 7.16.

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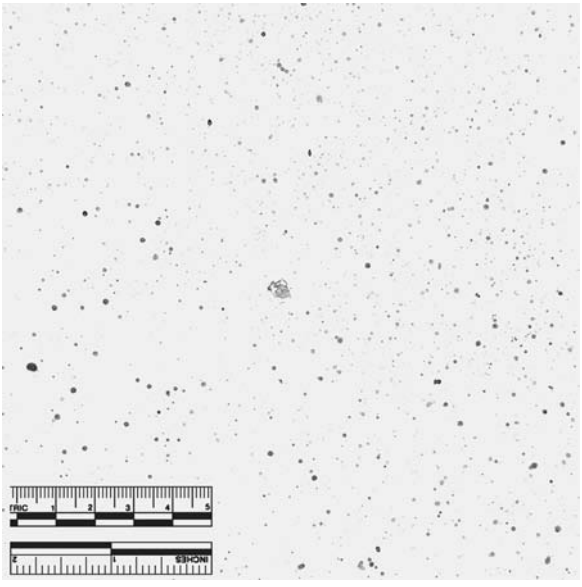

Figure 7.16 This pattern shows the level of dispersion present in a gunshot event when the target was 18 in. from the blood source. The pattern has a more dispersed nature with less of a misting effect.

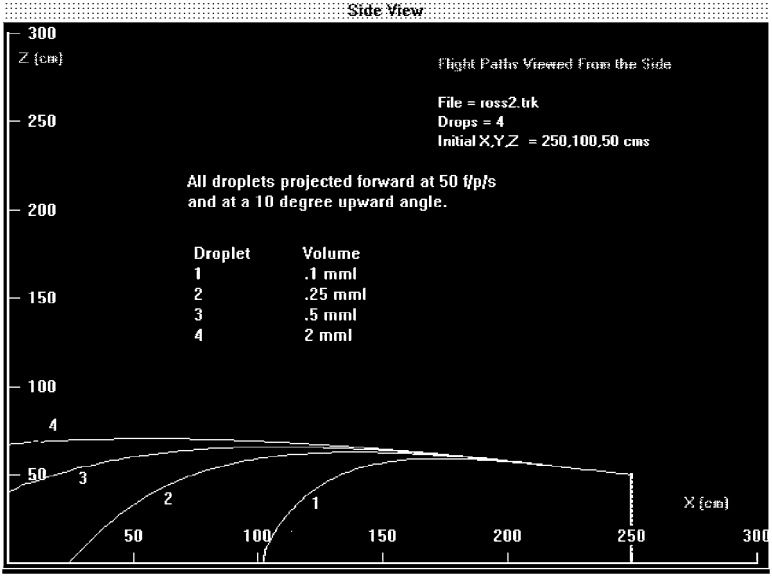

Figure 7.17 This *Tracks*® model shows four droplets projected along the same initial path at the same speed. Note that all four follow different parabolas, with the smallest droplet (Droplet 1) traveling the shortest distance. This is the result of air resistance on the droplet, which is inversely proportional to the size of the droplet.

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also a consideration when viewing the dispersion of patterns, particularly those found in "high-velocity" impacts.

Other factors affecting 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 strikes or surfaces on the weapon may preclude blood ejecting in a symmetrical fashion.

Because it is not evident based on empirical data, the analyst should never accept that a given weapon will produce a singularly distinctive pattern each and every time it is used. Minor variations in the weapon's contact or application may result in significantly different effects when re-creating 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 re-creation 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 fact 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, 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.

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 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 7.18 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 7.19 shows the spatter present on the right back shoulder, labeled C. 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 7.20 shows a close-up of the pattern labeled B. Barely 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

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Figure 7.18 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 or possible cast-off stains on the mid-back. Both stain patterns furnish information based on the dispersion characteristics.

overlaying the larger. These stains were determined to be consistent with the second victim's blood. They establish 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 or bloody surface 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 original direction of the projectile, but may also create a back spatter effect (Figure 7.21).

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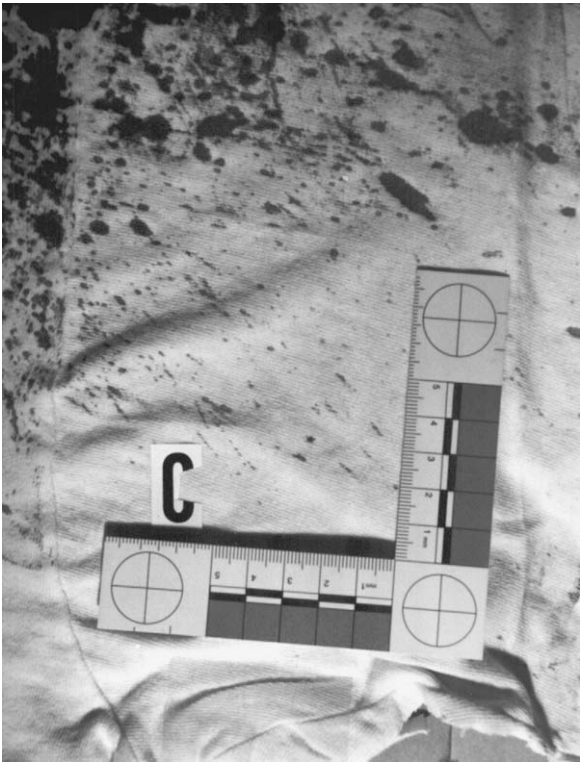

Figure 7.19 A close-up photograph of Stain Pattern C. This pattern could be correlated to a number of small scene patterns on surrounding objects based on the dispersion and radiating effect, which effectively placed the victim in a specific position when this event occurred.

Obviously, forward spatter patterns from gunshot injuries occur only when there is an exit wound, whereas back spatter is always possible. Figure 7.22 graphically depicts 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. (Color Figures 4 and 5 show two additional photographs of this cloud of particles.*)

With regard to the conical shape in both forward and back spatter patterns, the rules of dispersion also hold true here. 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. In other words, the pattern will appear as if someone used a spray can to

* Color Figures 4 and 5 follow page 134.

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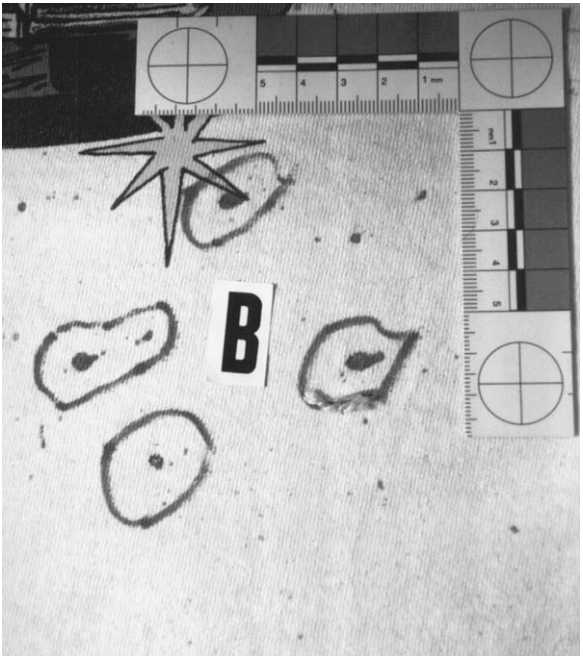

Figure 7.20 A close-up photograph of Stain Pattern B from Figure 7.18. The small spatter intermixed in the larger stains was initially thought to be associated with a single event. DNA analysis established that the source of the smaller stains was the victim's wife, who was also beaten. Due to the small 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.

create it. Further away, the pattern becomes more dispersed, with fewer mist-like stains, eliminating this effect. Refer to Figure 7.15, which shows this mist-like pattern. In Figure 7.16, the stains are more dispersed as a result of being farther from the blood source.

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]

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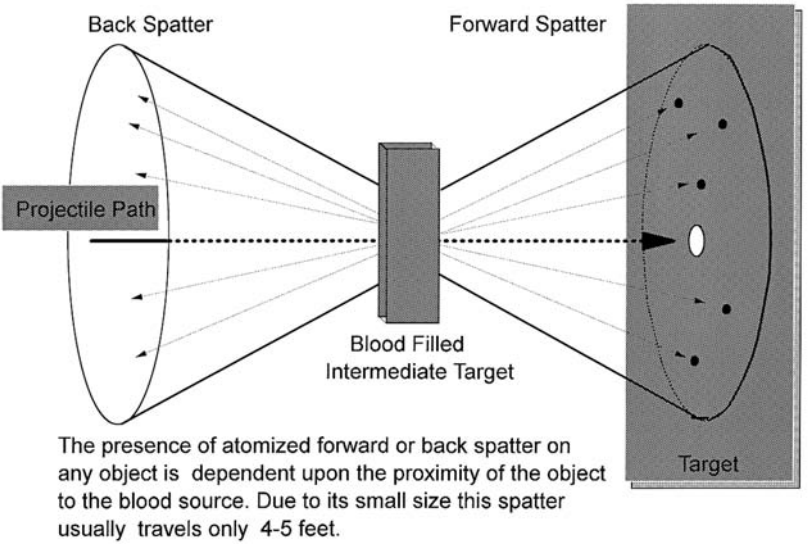

Figure 7.21 Spatter resulting from a perforating gunshot produces both forward spatter and back spatter. The individual spatter project out from the source (e.g., the body) in a cone-shaped pattern, but most do not travel far because they are quite small.

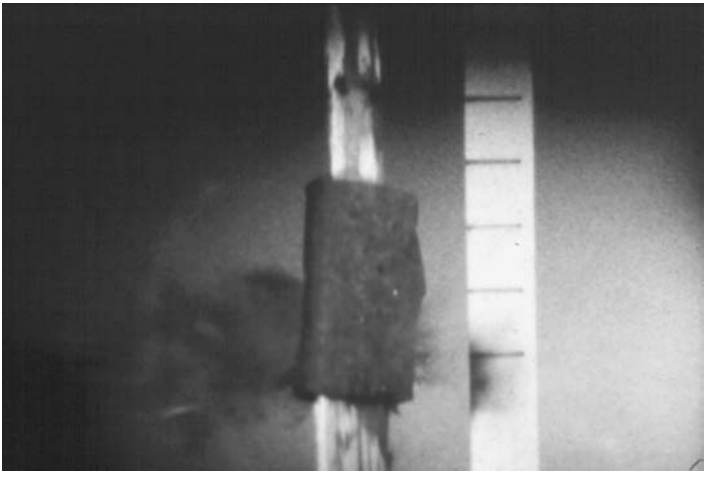

Figure 7.22 In this stop-motion photograph we see the development of the cone of spatter after a bullet passes through a bloody sponge. The bullet is traveling right to left. There is a distinct development of fine droplets of blood in the forward spatter, but those projected to the rear are fewer in number.

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Anyone conducting similar experiments will routinely find spatter from gunshot 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-oriented spatter, both forward and back.[21] Second, he has 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 on both the projectile mass and projectile velocity, whereas 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 temporary wound cavitation. This temporary stretching of the surrounding tissues then collapses back to the final defect size. 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.

An interesting effect related to gunshot spatter and this squeezing action is when two or more successive shots occur. The first wound usually bleeds

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Figure 7.23 Forward spatter resulting from several gunshot wounds to the head. The pattern in and around the seat lever was associated with the final perforating shot.

during the intervening period between shots. When a second shot impacts the body, the tissues surrounding the first wound compress, 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 wounds are to one another, the more dramatic the effect. This condition certainly indicates that the mere compression of a wound track by the energy of a passing projectile is sufficient to eject spatter from a wound opening. (Color Figures 6 and 7 are case examples demonstrating this effect.)*

Gunshot Pattern Shapes and Dispersion

In considering gunshot spatter pattern shapes, 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.

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 (Figures 7.23 and 7.24). In other instances the spatter may be extremely limited or nonexistent. For head, chest, or heart wounds, there is no way to predict when spatter will occur. Characteristics of the wound and positioning of clothing, hair, or other items can affect the presence of spatter or lack thereof. The size of spatter in these instances may also

* Color Figures 6 and 7 follow page 134.

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Figure 7.27 Back spatter present on the hand of a suicide victim. Note also 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 stain cannot be reconciled as being from the initial deposit of back spatter because 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.)

Expiratory Blood

When a victim suffers bleeding injuries to the mouth, nose, throat, or lungs and continues to breath, 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 (Figure 7.28). At times these stains can mislead the analyst, and their similarities demand proper evaluation. Figure 7.29 depicts expiratory blood on the sleeve of a man who came to the aid of a shooting victim.

Oftentimes, expiratory blood that mimics gunshot spatter is less vivid in its coloration. It may give an indication of being watered down and very likely will exhibit a focused direction for the pattern. There may also be evidence of air bubbles in the pattern, or traces of popped air bubbles. Expiratory blood is most often recognized by correlating the position of the spatter with bleeding injuries observed on the nose, mouth, or airway. (See Color Figures 8 through 11, which depict examples of bubbles present in an expiratory bloodstain pattern.*)

* Color Figures 8 through 11 follow page 134.

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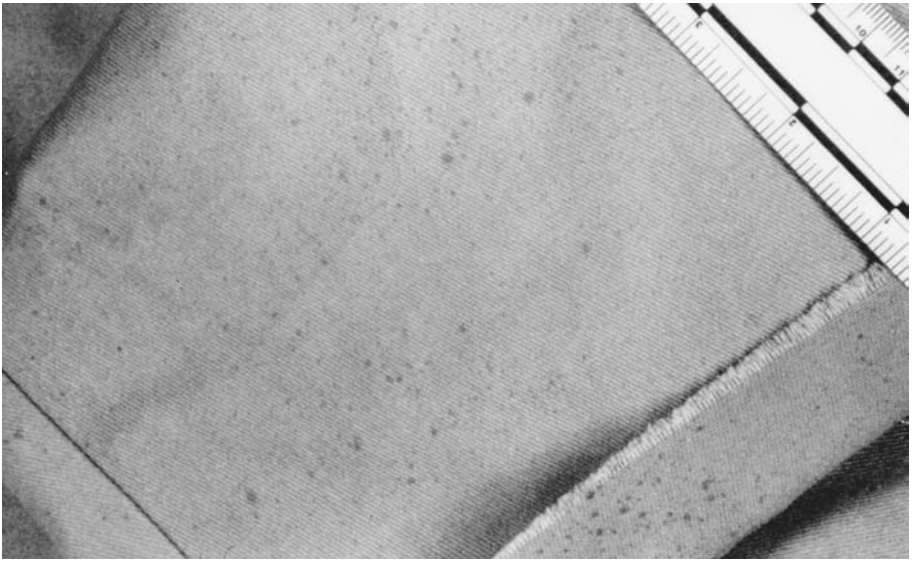

Figure 7.28 An example of expiratory blood. The subject was wearing these cutoff jeans as he stood over the victim, whose throat was cut. Stains are evident on both the inside and outside of the pant leg. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, Oregon.)

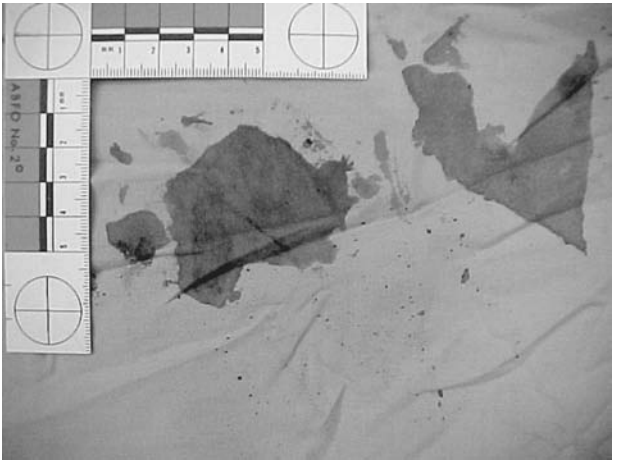

Figure 7.29 Expiratory blood on the sleeve of a man who came to the aid of a shooting victim. Initially of concern, the presence of similar spatter from the expiratory event elsewhere in the scene helped in understanding the true mechanism of creation of this pattern. Taken by itself, this pattern is certainly consistent with spatter associated with gunshot.

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Fly Spots

Although not true spatter, another pattern often confused with spatter is the "fly speck" or "fly spot" pattern. Flies present within the scene will feed on blood found there. This blood is both tracked about and regurgitated by the flies. In 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 (Figure 7.30). Most 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.

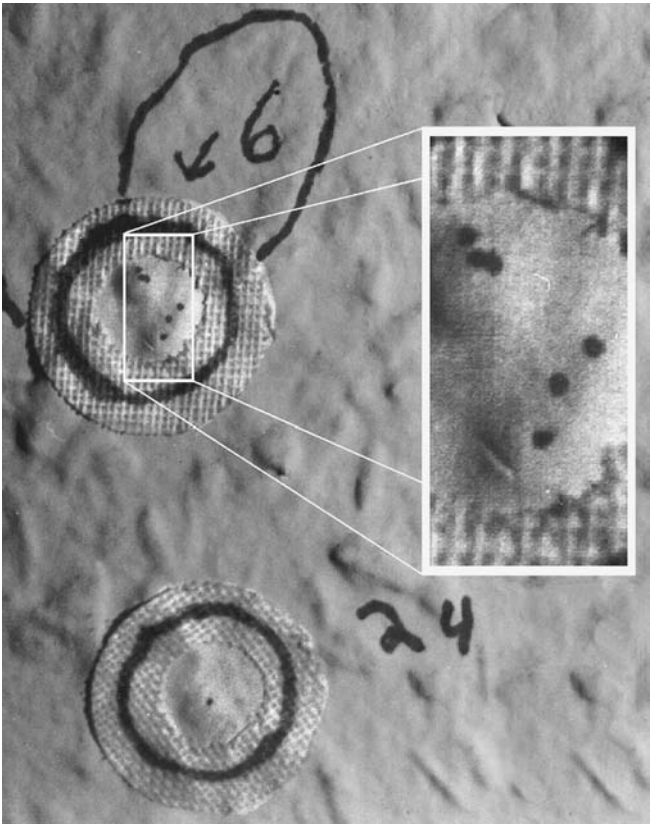

Figure 7.30 An example of fly spots. The small, circular stains found within the gummed hole reinforcements were initially thought to be related to a gunshot event. The insert demonstrates just how symmetrical the spots are. Only after considering position, time, and the entire scene did it become evident they were not spatter.

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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 in 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 within 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, as MacDonell put it, is "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 with the item's distance from the target.

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 gunshot situations, spatter may form both as forward spatter, which is projected outward in the direction of the bullet, and as back spatter, which is projected back toward the weapon. This often results in deposits of spatter on the subject or other parties present at the time of 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 at or near the victim. These stains rarely travel beyond 4 ft from their source. When found on someone's clothing, it is difficult to refute that person's presence near the event.

Mimic stains may cloud the analyst's observation. Both expiratory blood and flies produce patterns that an analyst can misidentify as either gunshot or impact spatter. The analyst, if knowledgeable about such stains, is less likely to make such a mistake when considering the full context of the scene.

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Given the discussion of patterns and knowledge of defining the point of origin, analysts have tools with which they may define clear information relevant to where in the scene these spatter events occur and distinguish one event's spatter from another.

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Characteristic Blood Patterns That Aid in Analysis

8

This chapter deals with some of the more common patterns the analyst may encounter. Definitions for these stains are given in Chapter 3. Here we discuss some of the ways they assist in reconstructing the events in question.

Cast-Off Stains

Cast-off stains occur from two actions: centrifugal force as a bloody object is swung in an arc (Figure 8.1) and inertia at the cessation of the swing (Figure 8.2). These stains generally have a linear patterned feature, which makes them easily recognized. This linear feature doesn't mean they must all line up along 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 parts in the resulting pattern.

Cast-off patterns are important to analysis in that they identify at least a minimum number of blows struck during the event. By considering directionality of the individual stains in the pattern, the analyst can determine the forward and backward swings. As such, the analyst can group them, defining from this the number of blows evident in the pattern. Quite often analysts take this number and add an additional blow, assuming that the first blow struck by the assailant produced insufficient blood to cause a cast-off.

What this information cannot tell us is the total number of blows delivered during the event. That number is very likely higher than the number of blows evident in the cast-off pattern. The subject, however, cannot refute this minimum number of blows. The subject's story must account for the information evident in the pattern.

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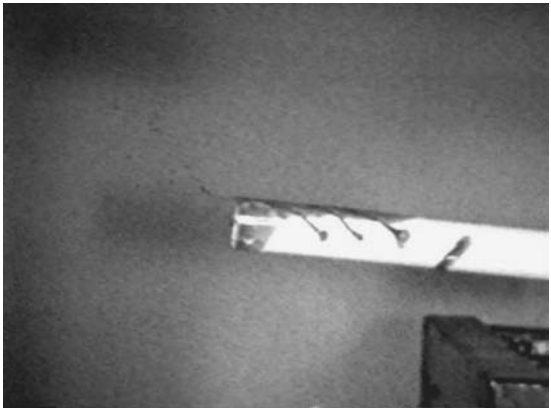

Figure 8.1 An example of cast-off from a bloody object. The centrifugal force carries the blood away from the object, resulting in a pattern that helps identify the arc and direction of the swing. (Photograph courtesy of Metropolitan Police Forensic Science Laboratory, London, England.)

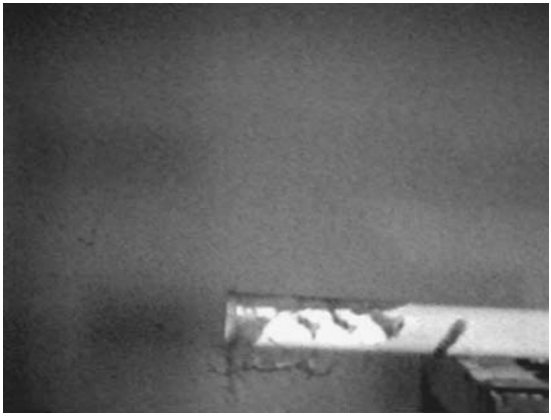

Figure 8.2 At the end of the swing, blood is also cast off from the object as a result of the cessation of the swing and the inertia of the blood. (Photograph courtesy of the Metropolitan Police Forensic Science Laboratory, London, England.)

The nature of the item from which the cast-off occurs has a distinct effect on the resulting stain. A broad or multisurfaced object will result in a distinctly different cast-off pattern than an object with a single sharp edge or a smooth surface. Figure 8.3 demonstrates the cast-off created by three different weapons. Pattern 1, the cast-off to the left, shows a distinctly linear pattern, with small individual stains. The width of the pattern is quite compact. Note the points along the pattern where dual drops seem to lie in close

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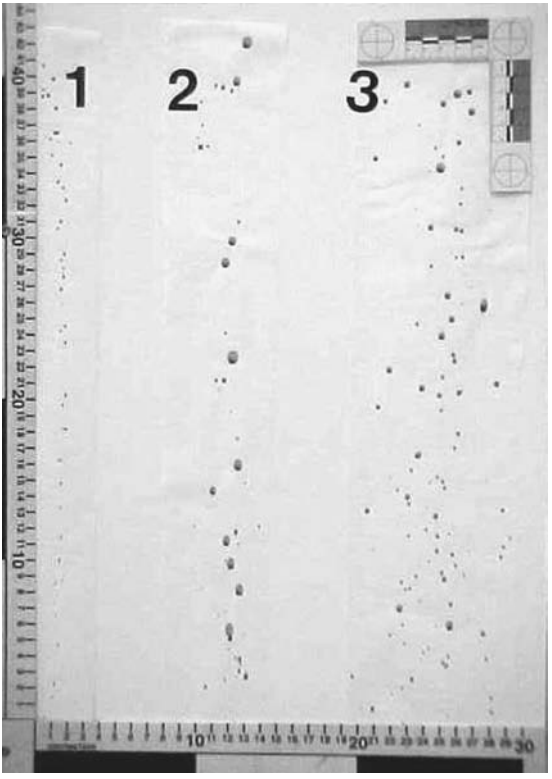

Figure 8.3 Cast-off patterns created by three different weapons, each swung one time. Pattern 1 has a very linear form with small-sized stains. Pattern 2 is linear but the stains are dispersed across a broader area and the size of the stains is much larger than those in Pattern 1. Pattern 3 has a very broad swath in which the stains are dispersed and almost appears to be a result of multiple events.

proximity. This alternating (right to left) droplet characteristic occurs often with items that have a clear edge. Pattern 2, the middle pattern, has significantly larger individual stains. The path is still clearly linear but is less compact and wider. Pattern 3, on the right, has a less linear feature, enough so that on first examination one might believe it was from multiple swings of the weapon. The stains are larger and the width of the pattern is distinctly wider. Figure 8.4 shows the three weapons used to create the patterns. Sharp-edged weapons characteristically cause small stains with very linear patterns (Figure 8.5). Bats and clubs will create larger stains and wider patterns as droplets detach from a larger surface area. The board and items similar to it create this very broad pattern characteristic because there is a large surface area from which blood is cast off.

In circumstances such as Pattern 3 in Figure 8.3, the analyst can usually distinguish if the pattern is a single cast-off or multiple cast-offs. Within the

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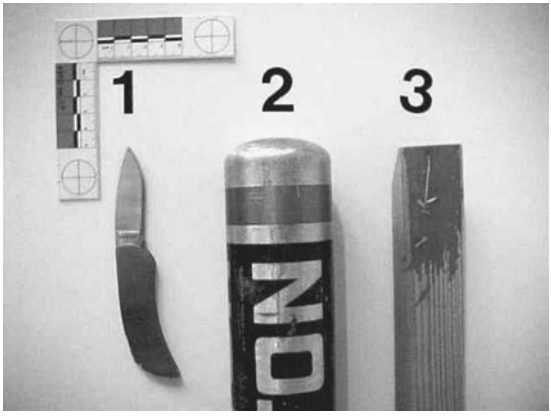

Figure 8.4 The three weapons that created the patterns in Figure 8.3. Knives tend to cause very linear patterns with small stains. Bats and clubs produce linear patterns, but their broad surface areas result in larger stains in the pattern. The flat, rough surface of the stick resulted in the release of stains across the entire surface area, creating the very broad pattern.

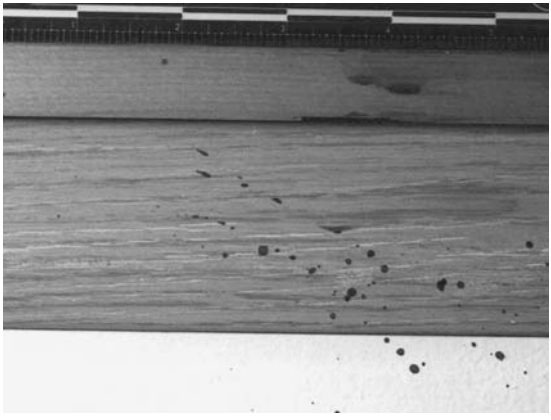

Figure 8.5 Cast-off patterns created by an edged weapon on a window sill. Note the small size of the individual stains and the short length of the pattern itself. Knives have little surface area on which the blood can accumulate, and very often create much smaller stain patterns.

scene there are usually sufficient distinct patterns to allow the analyst to recognize this wide pattern characteristic.

The volume of blood available during a cast-off event will affect the size and the number of stains. With less volume present for any given weapon, the stains will tend to be smaller. If a significant volume is exposed, the stains will tend to be large.

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In addition, cast-off stains may give indications as to the nature of the blow; that is, was the blow left to right or right to left? This orients any blows to the scene and may also indicate which hand the individual used to create them. This indication of handedness does not define the subject as either "right-handed" or "left-handed" in and of itself. 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 will translate 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.

Given several targets (e.g., walls and floors) on which a cast-off pattern is found, we can often orient the position of the individual swinging the item. At the onset of the swing, cast-off droplets strike the adjacent wall at 90°. As droplets are cast off farther into the swing, they strike at more acute angles, creating elliptical stains. When the relative position of the target changes, as in the juncture of a wall and ceiling, so too does the angle of impact. The analyst is likely to find 90°-impact droplets on both the wall and the ceiling. Correlating the two in relation to each other allows some indication as to the general pivot point of whatever item was involved (Figure 8.6).

We may also consider cast-off patterns and their respective change on the surface involved. Remember, the source of the blood in our cast-off pattern is invariably 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. This indicates the victim's position changed as the subject delivered the blows. One caution in considering cast-off patterns: they may result from actions by either the subject or the victim. The victim can also produce such patterns while swinging bloody appendages.

In situations involving exaggerated swings, it is not uncommon to discover small cast-off stains on the back surfaces of the subject's body and clothing. The cessation action at the terminus of the back swing may cast small droplets onto the shoulders, back, and legs (Figures 8.7 and 8.8). This condition depends on the nature of the swing and the position of the subject's body. For example, if the subject was kneeling we might expect him or her to have such spatter on the back surfaces of the lower pant leg. The analyst can correlate these spatter with soaked blood traces on the fabric in the knee area. Such evidence would certainly provide solid information regarding the subject's position during the attack.

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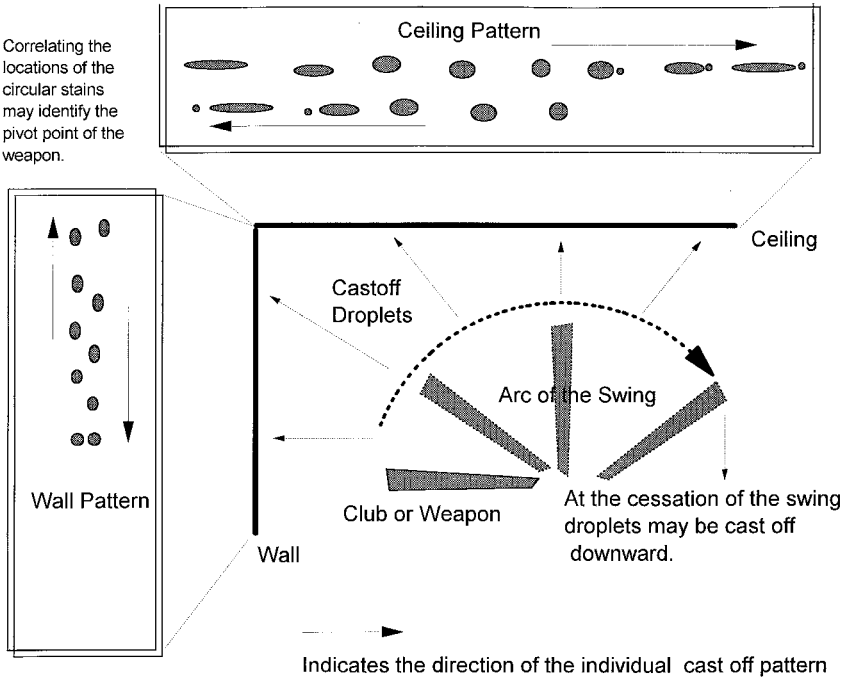

Figure 8.6 Cast-off patterns. Droplets flung from a bloody weapon or object impact surrounding surfaces at varying angles, but in a generally linear pattern. By considering directionality of the individual stains we can easily distinguish forward from backward swings. Consideration of the points on varying surfaces where we discover rounded stains may also identify the probable pivot point of the object involved.

Pattern Transfers

Pattern transfers are probably the most overlooked evidence within any given scene. As discussed, 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.

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." Granted, the analyst would prefer to make "identifications" based on individual characteristics, but that doesn't happen in every case. Nevertheless, toolmark and fingerprint examiners should be given an opportunity to consider such evidence in the hopes of making an actual identification.

Consider Figure 8.9. Present on the pant leg is a pattern transfer that also has a small unstained section within the pattern. This unstained section exhibits a distinctly curved edge. Figure 8.10 is the weapon that created the

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Figure 8.7 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.)

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 recreations, the analyst can easily correlate the class characteristics of the tool to those present in the stain. It is just as possible that a tool mark examiner may match individual characteristics caused by accidental marks or flaws on the tool.

Even if lacking such individual characteristics, class characteristics in the pattern are strong evidence. They often point the analyst to objects within the scene. The nature of these characteristics is unlimited. Such patterns include any number of swipes and wipes or compression contacts, all of which help the analyst understand what weapons or other items were in use.

In deciding if an object is or is not consistent with a pattern, experimentation by the analyst is necessary. Such experimentation occurs only after all other forensic examinations are complete. If comparing only the class characteristics of the item, the analyst may choose to use an item of similar construction. Do not, however, expect to make an exact copy of a scene pattern in every circumstance. The dynamics of how much blood

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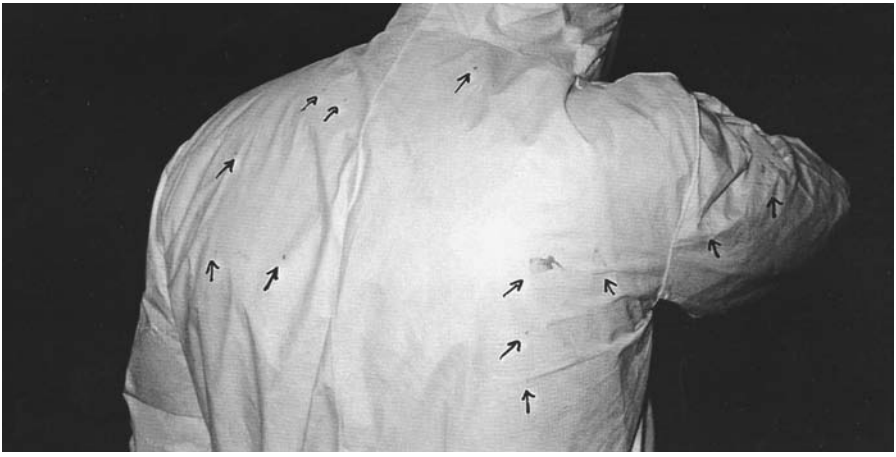

Figure 8.8 A close-up view of the student's back (from Figure 8.7). Each arrow points to spatter and other stains. In this instance, the spatter may be the result of both cessation action during the back swing and droplets thrown from the weapon in high overhead parabolic arcs. These types of stains are often found on the perpetrator's clothing. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

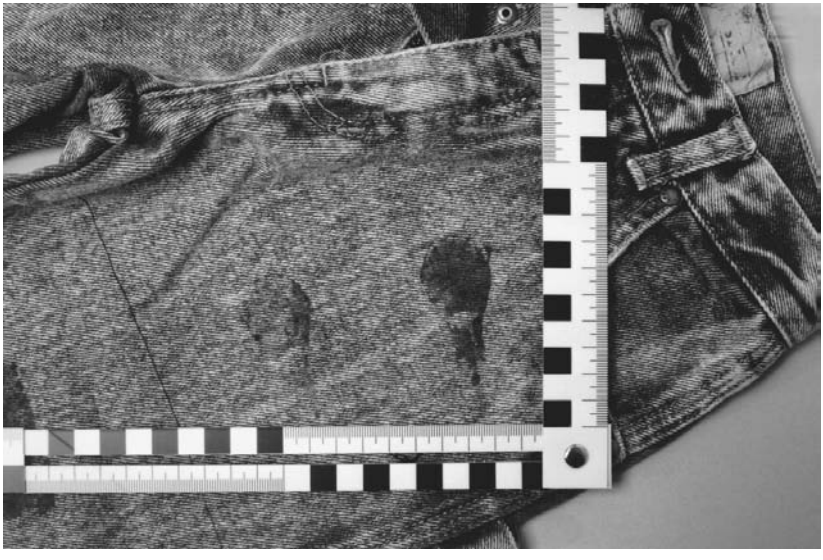

Figure 8.9 A pattern transfer on a fabric, in which the general characteristics of the object are evident. Note the elliptical voided area in the lower third of the pattern on the right. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

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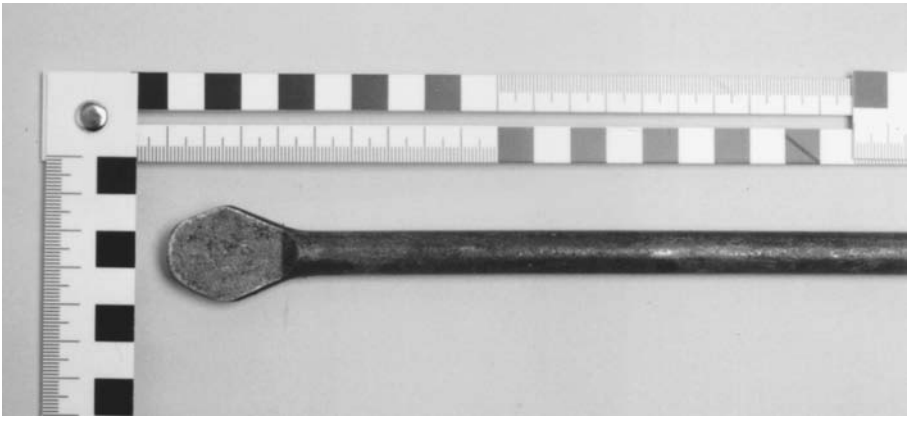

Figure 8.10 The tool that created the pattern in Figure 8.9. Note the beveled edge where the tool head and shaft come together. This characteristic is clearly visible in the pattern in Figure 8.9 as the elliptical area void of blood. (Photograph courtesy of Jouni Kiviranta, National Bureau of Investigation, Helsinki, Finland.)

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 events in absolute detail.

There are two basic approaches to evaluating pattern transfers. The first considers looking for a unique pattern within the stain in question and comparing that defect to the standard, whereas the second starts with characteristics in the standard and looks for similar ones in the stain in question.

Don Coffey offers this approach to the first method:

- Seek a landmark in the stain in question — 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.
- As a result 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 stain in question with a standard.
- The more eyes viewing the stain the better, because this eliminates tunnel vision on the part of the analyst.[1]

The second method of comparing pattern transfers begins with the standard. Our initial evaluation of the scene pattern may direct us toward some

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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 to the analyst.

With regard to patterns and the dynamic nature of their creation, how 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 classic butterfly pattern caused when a bloody knife is wiped with a fabric. 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 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.

The classic butterfly pattern, associated with edged weapons, often provides very distinct information regarding the features of the weapon creating it. Figure 8.11 shows an example of a slightly separated butterfly pattern. In the pattern is a clear representation of one side of the blade. The edge of the backstrap of the blade and the blade itself are quite distinct. Measured at a point about 30 cm from the apparent tip, the width of the pattern is 17 mm. Figure 8.12 shows the weapon that created the pattern. A measurement of the blade at the same point shows the width to be 17 mm. In case examples, however, the amount of blood evident in the pattern is often less than that found in a laboratory-produced example. Figure 8.13 shows a case example of the butterfly effect. Present just below the ruler and above the shadow of the blade you can see the pattern caused by the backstrap when the cloth was laid over the knife.

Knives are not the only items capable of creating a distinct pattern; Figure 8.14 is an interesting example of a peculiar pattern. This pattern transfer on cloth showed two linear features that were almost at a 90° angle to one another. When measured, however, the angle was actually 88°. A shotgun used and present in the scene had previously been shortened by the owner. The owner hand cut the barrel himself. The barrel was cut at an angle consistent with the angle in the pattern. During re-creation attempts, this particular weapon was bloodied and tossed down onto a similar surface (a pillow), resulting in a pattern nearly identical to that found at the scene.

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Figure 8.11 A butterfly pattern transfer created by the wiping of an edged weapon on cloth. Characteristics evident in the pattern include the backstrap of the blade and the general blade dimensions. The backstrap 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.)

The use of "screen positives" is a functional method of comparison for pattern transfers. This method is based on the work of Peter McDonald, in his book *Tire Imprint Evidence.* McDonald stresses that "screen positives are the most effective way of making visual comparisons."[2] The method involves making clear transparencies of the standard and stains in question 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. This technique works effectively when considering many types of pattern transfers. Don Coffey cautions the analyst in its use, however, because the method is expensive and point-to-point comparison is not always possible.[3]

In the crime scene, the most often encountered pattern transfers are fingerprints, handprints, and foot or footwear prints. All of these 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 specific actions by the individuals involved.

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Figure 8.12 The knife that caused the pattern in Figure 8.11. Although there are no evident individual characteristics present in the pattern, we can still compare general dimensions (e.g., blade width and backstrap 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.)

Another classic pattern transfer is the hair swipe. These patterns often show characteristic bifurcated endings (Figure 8.15).

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 as police, medical, and coroner personnel move items during scene processing. If an object is still wet and then moved it is likely to cause a transfer. In addition, these same personnel are themselves moving in the scene and may track blood. Figure 8.16 depicts a shoe pattern on the carpet adjacent to the bed. Figure 8.17 depicts the scene prior to disturbance. The shoe mark is noticeably absent and is obviously a post-incident artifact.

Finally, when the victim is placed into a body bag extraneous blood often flows; this can destroy existing patterns and create post-incident patterns. If the victim's clothing has spatter or stains of significance noted at the scene, it's best to consider removing the items there. This will preclude marring the patterns. Of course, any decision to do so must be considered in light of all investigative issues and approved by the appropriate coroner or medical examiner.

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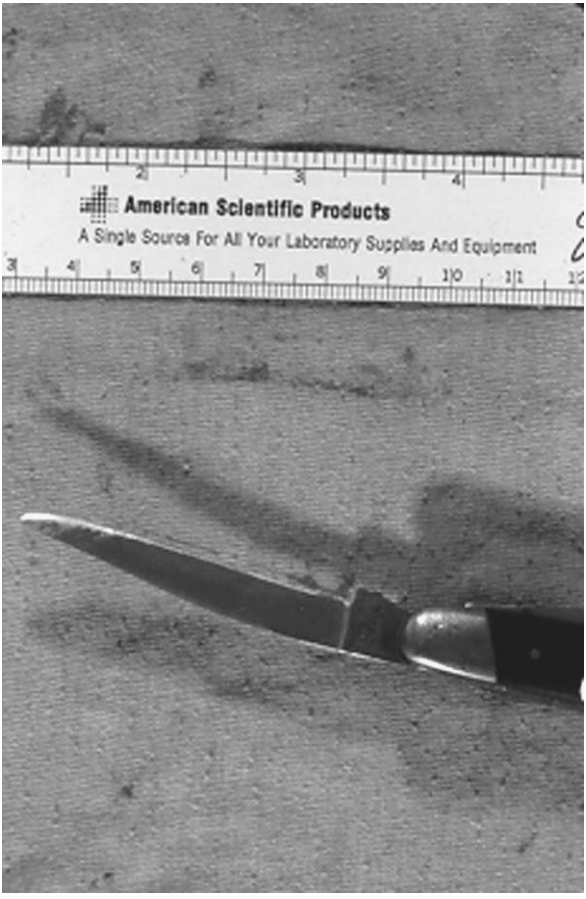

Figure 8.13 An example of a knife pattern transfer. The knife has been placed directly over the pattern after analysis in order to take this photograph. Case examples of butterfly patterns often exhibit less blood in the pattern than those created under laboratory conditions. Nevertheless, distinct features are often evident. Note the L-shaped feature in this pattern that matches with the base and tang of the pocket knife. Also note the opposite wing of the butterfly pattern (where the cloth overlay the top side of the blade), which is about 10 mm below the ruler.

Projected Blood

Projected blood patterns are characterized by two features: volume and spines. The most typical naturally occurring projected patterns are arterial gushes or spurts. They are recognized by the spines present in individual stains, which reflect both the presence of force behind the projection and the volume of blood projected. As MacDonell illustrated, such patterns as

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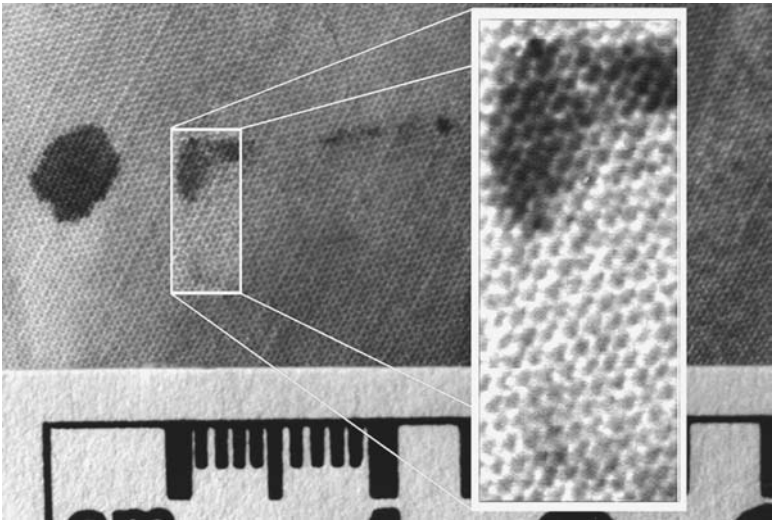

Figure 8.14 Oftentimes a pattern transfer is anything but specific and therefore not considered of value. In this instance we have a simple stain that suggests the corner of some item. On closer examination it became evident that the edges of the two stains were not at right angles to each other, but rather formed an 88° angle. A weapon bloodied during this event had a distinct cut that formed a similar 88° angle. During re-creation attempts, the examiner was able to recreate the pattern using this cut area of the weapon.

a whole may look quite different, depending on the location of the artery breached.[4] Yet, the pattern will in some fashion reflect the spines. These spines indicate the blood struck the target with force. Many times these patterns will show the pressure fluctuations of the circulatory system, with peaks and valleys evident. Figure 8.18 depicts an arterial gush, and Figure 8.19 shows an arterial spurt pattern resulting from a severed carotid artery. Figure 8.20 shows another arterial spurt. Note the large-volume elliptical stains on the doorway; these stains are another classic characteristic often found in arterial patterns.

An important correlation for arterial spurts and gushes is the condition of the victim. Given a breached artery and a live victim, some evidence of the projected blood will be found. Lacking such stains, one would surely question whether the victim's heart was beating at the time the artery was breached. Again, volume and projection are the characteristics the analyst looks for. Passive flows and drips will not suffice to explain the lack of these gushes. It is possible that clothing or other items over the wound may block the overall development of the pattern, but if the victim was alive there will usually be evidence of the arterial wound.

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Figure 8.15 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.)

Flow Patterns

In considering flows found in the scene, the primary issue for the analyst is to distinguish passive from active. Passive flows occur as a result of gravity and body position. They have limited investigative importance, other than 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.

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Figure 8.16 An evident shoe mark pattern transfer on the carpet at a death scene. This photograph was taken after removal of the victim. Compare this to Figure 8.17.

Figure 8.17 The same area as shown in Figure 8.16 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 in recognizing them.

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Figure 8.18 An arterial gush. The pattern on the sidewalk resulted from a wound to the heart. As with most projected blood patterns, both volume and spines are evident throughout the pattern.

With regard to positioning, consider an example in which we find a flow pattern on the face of a victim. The victim is found flat on his back in the scene, but the flow runs up the nose (i.e., toward the ceiling), not down. This gives the analyst a clear indication of a change in the victim's final position. At some point the victim must have been positioned with the head slightly downward. Recognition of such an abnormal blood flow provides the analyst with specific indications of the victim's position. Blood flows will always obey gravity.

For example, in Figure 8.21 the reader will observe two minor flows that create an X. One is disturbed, whereas the other shows a distinct dogleg, with motion toward the upper right-hand corner of the picture. In this instance

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Figure 8.19 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 needle. When directed straight toward the target, arterial spurts often demonstrate this characteristic. (Photograph courtesy of T. Daniel Gilliam, Larimer County Sheriff's Department, Colorado.)

the subject claimed the victim was sitting upright when these two flows occurred. However, the dogleg flows from the victim's stomach upward toward the victim's armpit. Given the direction of the flow and the congealed blood at the end of the flow, one cannot reconcile the subject's claim as to the positioning of the victim. Figure 8.22 is another example of an abnormal flow. By considering the effect of capillary action in relation to the flow pattern's position, it is evident that the victim was moved at some point following the creation of the flow.

Additionally, the interruption of flow patterns may 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

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Figure 8.20 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 characteristics. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, Oregon.)

also indicate sequencing and passage of time between the flow, the interruption, and the subsequent removal of the interruption (Figure 8.23).

Voids and Ghosting Patterns

Voids are typical in spatter pattern situations but also appear in other types of stains. 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.

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 8.24. A spatter-producing event below and to the right of the picture frame resulted in distinct demarcation lines where the frame interrupted the pattern's development. One demarcation is evident on the right side of the frame and a second is evident above the frame.

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

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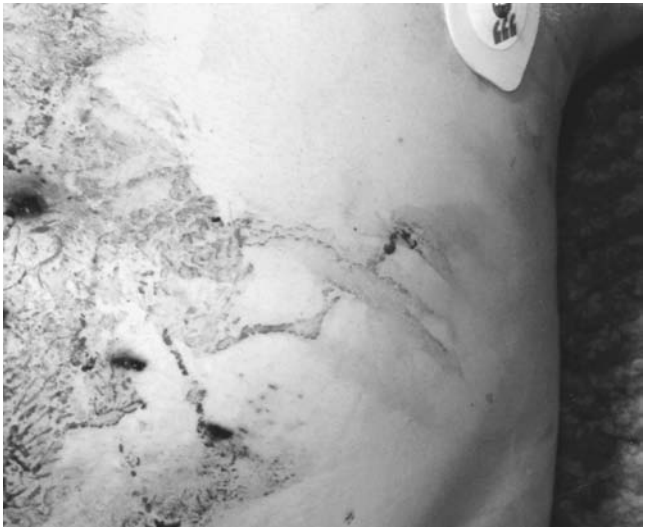

Figure 8.21 Blood flow inconsistencies. Note the two small flows evident on the torso that create an X. This pattern could not be reconciled with the subject's story. The subject claimed the victim was sitting when the flow occurred, but the flow that makes the distinct dogleg (in the lower portion of the X) is actually flowing toward the victim's armpit.

and a pattern that simply stops (Figures 8.25 and 8.26). Voids may occur in either instance, but in the latter the analyst may be less confident about viewing an actual void. If the pattern ends abruptly with a distinct linear demarcation it is more probable the pattern represents a true void. If no true demarcation is present it may simply be the natural end of the pattern.

Voids are often functional for establishing body position of the victim or assailant 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 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. Figure 8.27 demonstrates two voids. In the central area of the hallway it is evident where the general position of the body was at the time of the spatter-producing events. At the bottom center of the picture there is an area completely void of spatter, with clear, sharp, demarcated edges. This demarcation indicates that some other item was in place at this location during the event and was subsequently moved.

Pools and Standing Blood

The analyst may also find many instances of pools or standing blood within the scene. By considering the drying time and clotting time of blood and

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Figure 8.22 An abnormal flow pattern in a murder scene that was staged to look like suicide. The blood present on and around the arm is obviously inconsistent with the final position of the victim. The flow from the wound fails to follow the line of the victim's current body position (capillary action) and indicates some motion of the body following the flow. (Photograph courtesy of Barie Goetz and Charles Green.)

estimating the amount of bloodshed, the analyst can detail information about the overall incident.

Drying time and skeletonization are both important. Like any fluid, when shed blood reacts to its environment, and the manner in which it reacts points the analyst to the passage of time within the scene. Of particular 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 bloodstain within 50 s after being exposed.[5] In some instances this ring may appear earlier. This effect is referred to as skeletonization. The dried outer ring evident in the stain cannot be wiped away even if the stain is vigorously wiped. Depending on environmental factors and the surface on which we find the blood, a droplet may take more than 20 min to dry completely. The skeletonization effect, however, consistently occurs not later than 50 s after initial bloodshed (Figure 8.28).

To establish actual drying times of droplets, the analyst must consider the environmental conditions of the scene. By experimentation, the analyst

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Figure 8.23 An area of congealed blood that holds a child's handprint. As the flow occurred, the blood congealed while the hand was 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. (Photograph courtesy of Edmond Police Department, Edmond, Oklahoma.)

may 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 or was not disturbed immediately after its creation.

Clotting also gives the analyst an indication of the time that passed between bloodshed and the observation of clotting. Anita Wonder defined three stages for clotting: 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 at which, if disturbed, no flowback 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]

Obviously, categorizing the stage of clotting is a parameter decision. We strongly caveat the times involved, because that time is affected by temperature, humidity, and the surface on which the blood was shed. Laber and Epstein found similar clotting times ranging from 5 to 40 min. The primary environmental factors they consider important to the clotting process include surface of the target and temperature.[7]

In addition to the passage of time since the bloodshed, another issue often raised about blood pools is the total volume represented by the pool.

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Figure 8.24 This photograph demonstrates the nature of the demarcations typically found in voids. Note the absence of spatter along the right edge and top of the picture frame. (Photograph courtesy of Det. Mark Nelson, Springdale Police Department, Arkansas.)

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. There are instances in which cases were adjudicated without a body, in part because the blood volume made it clear the individual 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 that consider all the factors listed above. Hopefully, any result would include a level of confidence on the total blood volume developed through some type of statistical analysis.

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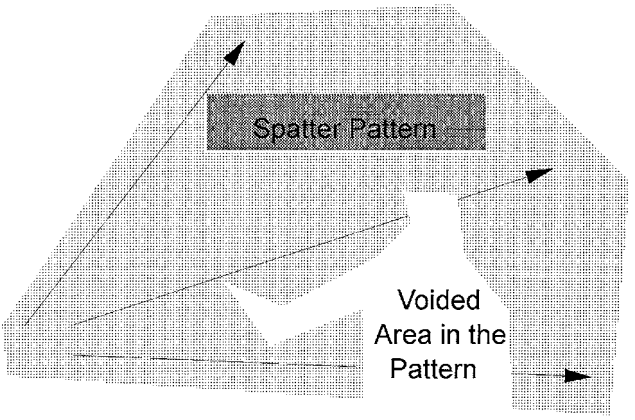

Figure 8.25 Interrupted pattern with an obvious void. Voids of this nature are easy to identify because the pattern clearly continues beyond the limits of the voided area. Often the shape of the void will assist the analyst in identifying the object that intercepted the spatter or blood.

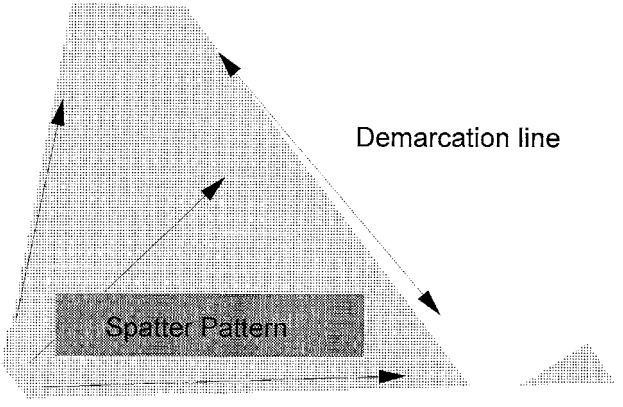

Figure 8.26 A less evident void situation. In this instance we may be viewing a void (e.g., the area to the right of the demarcation line), but it is also possible we are simply viewing the natural termination of the spatter pattern. In a pattern of this nature, decisions relating to whether this is or is not a void require a level of caution.

Lee and coworkers 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 include:

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Figure 8.27 Multiple void patterns in a hallway. The primary void is evident where the body was positioned as the events took place. A more defined void is centered at the bottom of the photograph with three clearly demarcated sides. One runs slightly diagonal to the square piece of tape, and two more clearly demarcated sides are to the right and left of it, forming the void itself. (Photograph courtesy of Steve Chancellor, United States Army Criminal Investigation Command.)

- Removing and weighing the actual blood crust present on nonabsorbent surfaces and multiplying that number by the constant.
- Weighing the substrate and blood crust, determining the weight of the substrate alone, subtracting this weight, and then multiplying the remainder by the constant.
- Determining the area of substrate covered by the blood, weighing a single unit (e.g., a square centimeter), and multiplying by both the constant and the total area.[8]

Another method for estimating blood volume is a wet volume estimate, in which the analyst attempts to create a similar-sized pool or stain. The first step is to measure the overall dimensions of the stain in question and define the total area within the stain (Figure 8.29). Using a similar substrate, the analyst then pours whole blood onto the surface in a slow and methodical fashion (Figure 8.30), all the while monitoring the overall stain size as it develops. The analyst then measures the test stains to include (several tests may be necessary), defining their total area (Figure 8.31). This comparison of the area encompassing the standards may indicate to the analyst a rough estimate of the volume of blood present in the stain in question. Although certainly not absolute, these estimations of blood volume, wet or dry, do at times serve the investigative process.

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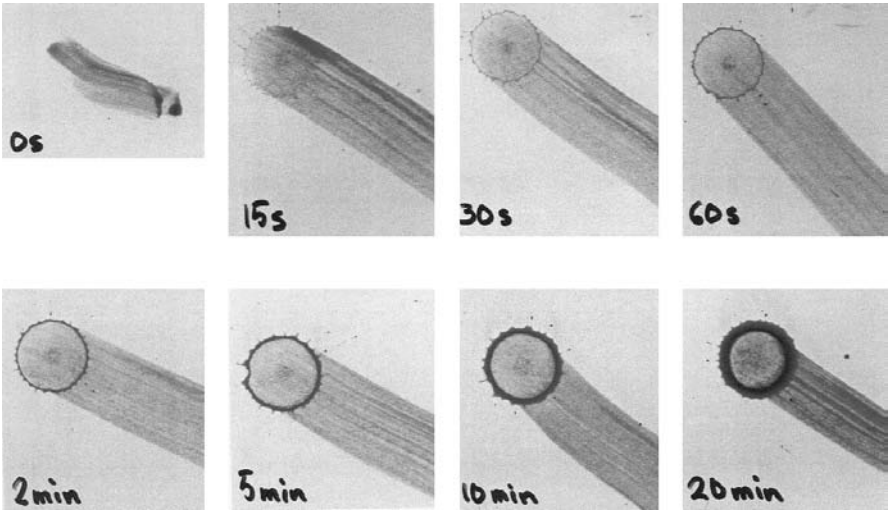

Figure 8.28 The skeletonization effect in a blood droplet. Each droplet was deposited and then wiped through at the time indicated. Note that 30 s after deposit a ring is present on the outside boundary of the stain. At 60 s the ring is readily apparent. This effect is known as skeletonization and allows 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 dependent on environmental factors.

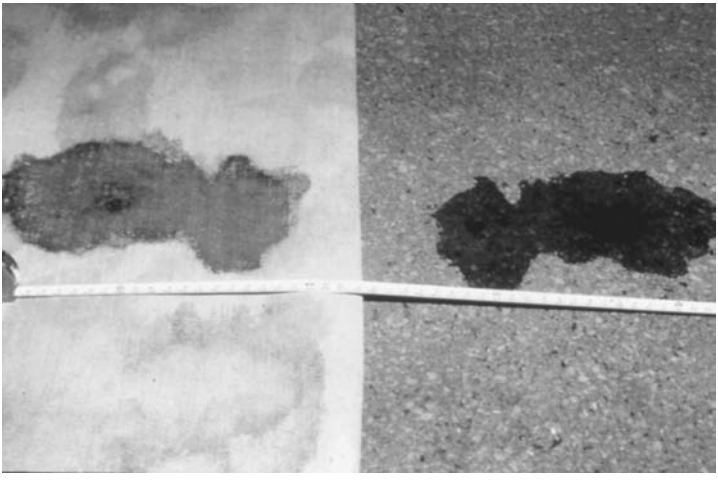

Figure 8.29 Estimating blood volume using a wet stain method. In this first photograph the stain in question is shown. The stain is measured completely and its total area defined.

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Figure 8.30 The next step is to create a similar-sized stain on a similar surface. Blood is added slowly and the size of the stain created monitored by the analyst. This is done in order to match the general dimensions of the stain in question as closely as possible.

Blood Dripping into Blood

The characteristic pattern of blood dripping into pooled blood is at times significant. This pattern occurs when a blood source, typically a bleeding person, remains in place long enough for dripping to occur. The pattern has two distinct features: the random satellite spatter surrounding the pool and the inverted 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 4. The satellite spatter that detach from the blossoms are projected outward from the pool. They create small (1-to 2-mm) spatters that show evidence of varying angles of impact. The spatter may radiate out from the pool for several feet. As a result of the rolling

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Figure 8.31 The analyst then measures the total area evident in the standards. This figure is compared to the area in the stain in question. This comparison, in correlation to the known volume of blood used to create the standard, allows the analyst to roughly estimate the volume of blood in the stain in question.

motion that may occur in the liquid pool (resulting from the droplet impacting the liquid), such satellite spatter are projected out from the pool in random directions. The resulting stains will show this random directionality. This type of pattern often mars other patterns of interest, particularly spatter patterns. Based on their small size, such stains may be confused with impact spatter.

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 (Figure 8.32). Obviously, the closer the vertical surface is to the pool the earlier in the parabola the interruption will occur. Thus the pattern evident on the vertical surface will show a voided area that resembles an inverted fan or V shape (Figure 8.33). The bottom of the V will be the point where the surface was closest to the dripping action. Figure 8.34 is an example of a typical drip pattern.

Drip 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. One caution, however, is that the item dripping (depending on the level of dripping evident) may be either a bloodied object or the subject. Care is certainly in order in trying to establish a specific source of the drip pattern.

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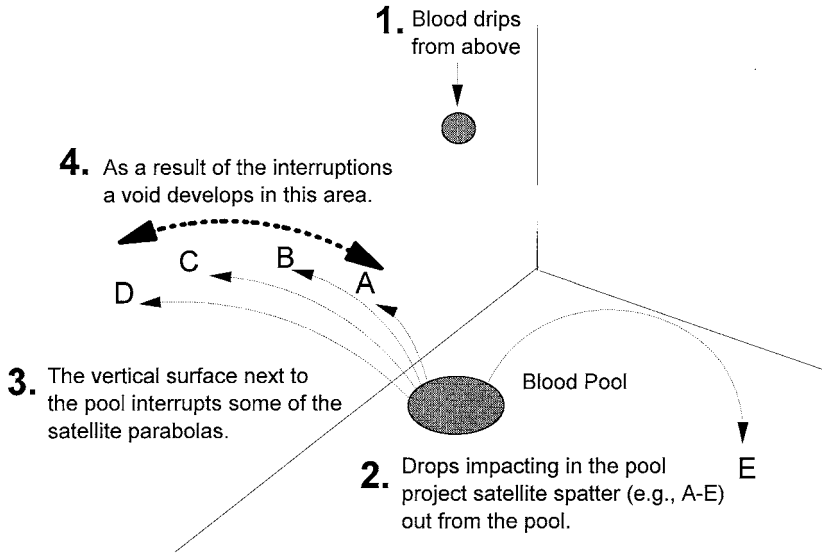

Figure 8.32 Drip pattern development on the adjacent vertical surface. (1) Blood dripping from a source impacts a static pool. (2) The impact causes satellite spatter to be projected out from the pool in every direction. Allowed to follow their natural parabolas, the spatter project away from the pool (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 and B). Droplets impacting the wall at more acute angles travel farther and thus attain a greater height before they impact (C and D). This causes a distinct arced demarcation in the pattern.

Patterns on Clothing and Fabric

The presence of patterns or stains on items of clothing and fabric present additional problems. For this reason we include these general considerations for examining such patterns and a discussion on the limitations that cloth material may inject to the analysis.

Often the analyst sees the clothing or fabric stains after the fact — not at the scene. The pathologist may provide a significant number of articles taken off the deceased victim. Post-incident artifacts are common in these instances. The analyst must ensure that the stains and patterns examined were in fact created as a result of the incident. Any number of stains may be produced during handling of the body at the scene and transportation from the scene. The "bag 'em and tag 'em" mentality can often destroy scene patterns or stains, by overlaying large saturation stains created when the body is sealed in the body bag. Scene investigators must be cautioned and taught

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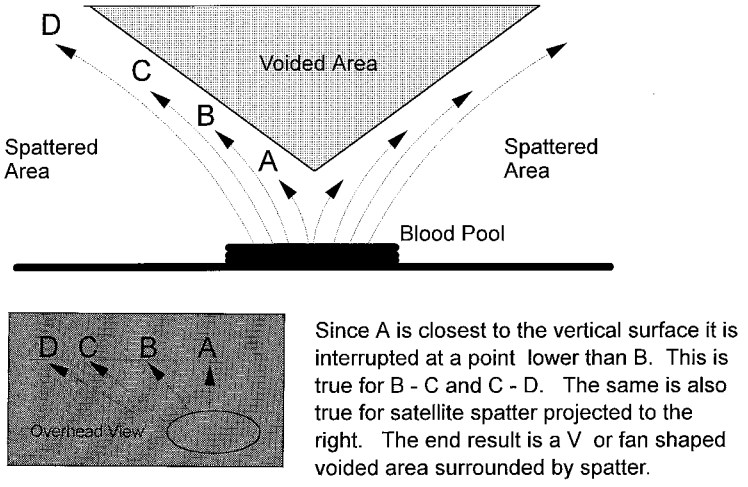

Figure 8.33 Because of these interrupted parabolas, the resulting spatter pattern will resemble a V or U shape, with a voided area in the center.

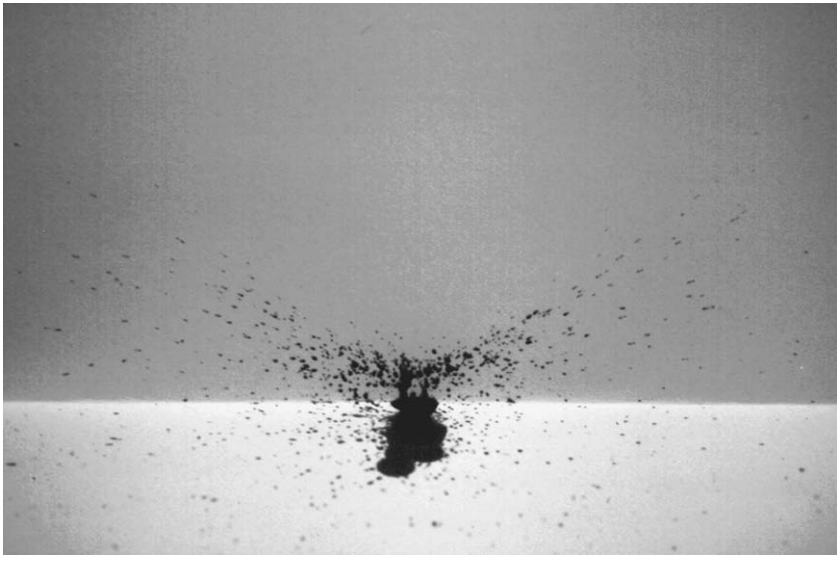

Figure 8.34 An example of a drip pattern on both vertical and horizontal targets. On the vertical target the V-shaped void results near the pooled blood. All about the horizontal target are small random spatter.

to document these types of patterns prior to bagging the body. From the analyst's point of view, it is important to verify stains found on the clothing with photographs or notes from scene investigators to ensure the patterns

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are scene related. Always be sure to inquire as to abnormal events during scene processing or the presence or evident activity of animals or insects on scene. All of these may result in "patterns."

Clothing examination must be thorough and orderly. This requires a location where the clothing can be laid out and manipulated. The area should be covered in clean butcher paper that is changed routinely to prevent cross-contamination between clothing items. Just the same, protective gloves and outerwear must be changed frequently. The examination process will require good lighting and magnification in and around the work area.

The specific methodology followed in the exam is of no importance, so long as it is thorough. Detailed notes, diagrams, and photographs will assist in documenting and recalling specifics found during the examination. As we discuss in Chapter 9, photographs of clothing and fabric stains should follow standard documentation procedures, ensuring proper introduction of scales and labels. Evidence photographs must clearly lead the viewer to the specific stains (Figures 8.35 and 8.36). The considerations of the clothing examination are no different from those for any other bloodstain: the analyst notes the characteristics present (e.g., size, shape, number, distribution) and attempts to identify the mechanism of creation.

One important consideration for clothing patterns is in balancing the need for serology samples from the clothing with the pattern analysis of the bloodstains. If the serology exam is conducted prior to the bloodstain exam, it may destroy the significance of patterns present or prevent the identification of patterns. There is no absolute answer, but to arbitrarily begin serology sample collection prior to documentation of the clothing condition will hamper the investigation.

The weave and condition of fabric can reduce the effectiveness of some bloodstain pattern considerations. As Slemko reported, "the distortion of a bloodstain on fabric is a function of both the ability of the fabric to absorb and the texture of the fabric."[9] Slemko's research found the greatest distortion of stains in highly absorbent material with course weave. Fabrics with tighter weaves or treated fabrics tended to show the least amount of distortion.[10] Thus the analyst must look at the properties of the fabric involved. Remember also that the fabric's age and condition (new vs. washed) can change these characteristics significantly.

Summary

The patterns included in this chapter are not meant to be inclusive of all those possible, but they do represent some of the more common considerations evaluated by the analyst. Recognition of the pattern is not enough; the

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Figure 8.35 Clothing exams require good-quality documentation just as any scene does. The photographs must take the viewer from the overall position on the clothes to the detail in the stain. In this example we see the label A and can define where on the pants it is.

analyst must consider what information these patterns illuminate regarding case specifics.

Cast-off patterns are extremely effective for defining events involving blunt trauma. They not only place people in the scene, they also allow the analyst to refute claims such as, "I only hit him once!" Pattern transfers document movement and contact of various articles and persons throughout the scene. They truly are the most widely encountered patterns in bloody scenes. Unfortunately, far too often analysts don't take the time to consider them in detail. Lacking an immediate pattern, analysts assume they hold no clues and are just smudges or smears.

Projected bloodstains like the arterial spurt help establish the condition of the victim. They often graphically depict the victim's subsequent movement

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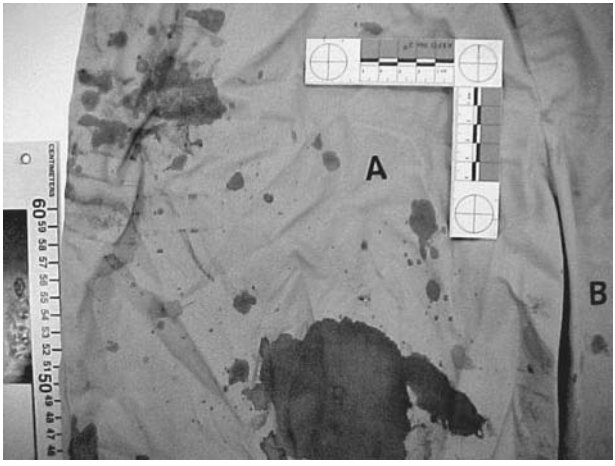

Figure 8.36 A close-up photograph of the detail in Stain A. Many clothing stains are critical, so there must be no question in the jury's minds as to their location.

in the scene. Flow patterns assist the analyst in positioning the victim or in recognizing some interruption of the flow. Voids not only assist the analyst in positioning, but also point to the nature of the object that caused the void.

Finally, blood pools and blood droplets, when considered with both drying and clotting times, provide information on the passage of time and sequencing of events within the scene. They can clearly refute statements of individuals who claim to have found the victim after the crime occurred. Drip patterns surrounding pools may also establish a delay, indicating the presence of an individual at a location for some period.

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Documenting Bloodstains

9

There is 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.

Proper understanding of issues of maintaining scene and evidence integrity demands an understanding of crime scene processing as a whole. 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

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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.

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 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 their 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 adversary 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 videotape recordings
- Sketching techniques
- Written reports for bloodstain documentation

Collection

It's not enough that the analyst recognize a pattern as defining some specific action. Without knowing who was involved, this knowledge does little to help define a reconstruction. Bloodstain evidence does not stand alone; in

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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) preparation techniques or short tandem repeat (STR). Both methods require a level of care in collecting and storing the specimen in order for it to be of later value.

Beyond documenting the stain's location, as a general rule the analyst should be concerned with five issues in collecting stains for subsequent serology analysis. These are:

- Proper discrimination between stains
- Sufficient identification of samples to patterns
- Sufficient collection of samples
- Precluding cross-contamination of samples
- 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 it back to that pattern. Ensure that the evidence collection notes and report have a clear correlating label that identifies the stain group involved. One of the authors (Gardner) prefers establishing a number for each stain group early in the scene processing. Any subsequent mention of the pattern includes a reference to that number. That 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.

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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 efforts help 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 technicians and 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, whereas others felt it was appropriate. Some thought scraping dried stains was a good method, whereas others felt swabbing was more effective. Because there is no consensus for the collection of samples, it is imperative that 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 on the advice of the serology department, may need to consider the collection of substrate control and blank

* The question was posed to the members of the FORENS-L Newsgroup on the Internet.

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control samples. Substrate and blank controls are still considered applicable to DNA analysis because they allow the serologist to recognize when contamination is present that may interfere with the analysis.

Whatever method is used, it is probably insufficient to collect a single sample from any given pattern. No matter what the sample 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 each 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. Don't use standard "crime scene kit" tools for collection. Instead, use either disposable scalpels or single-edge razor blades for scraping, sterile swabs, or disposable pipettes and syringes for collecting liquid samples. ***Always*** change the scalpel or pipette when moving from one stain to another.

Once the sample is recovered, the analyst must properly containerize it. Dried stains are best packaged in a druggist's fold, which is then sealed in another wrapping such as an envelope. Don't 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 a substance 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 and degradation of the sample.

Items stained with blood, such as clothing, should be thoroughly dried, then individually wrapped 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

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as a result of many factors, several of which the analyst can't control. It only makes sense that we eliminate sources of degraded samples whenever possible. The use of many chemical enhancement methods, which we'll discuss in this chapter, represents a major source for such degradation. Dr. 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 major concern.[1] Never arbitrarily spray enhancement chemical on any item of evidence until after the collection of proper serology specimens. If you have any questions on how to proceed, consult the supporting crime laboratory before acting.

Detection of Blood

At the scene the issue will often arise: What is this stain? Is it blood? Several methods of detection are applicable to the bloodstain pattern analyst. They include presumptive tests and enhancement techniques.

Presumptive Tests

Presumptive testing methods include Hemastix®, phenolphthalein, and leucomalachite green. Their function is simply to demonstrate with some level of confidence that the stain in question is worth the efforts of the analyst; if a stain isn't blood it doesn't make much sense to conduct a bloodstain pattern analysis. These detection tools, however, are presumptive; as such, confirmation testing by a serology lab should follow them.

Hemastix® is a simple presumptive test. Designed for hospital use, the item comes prepared as a short stick. The reagent present on the end of the stick is touched to a swab of the stain in question. The analyst then adds a drop of sterile water, and an immediate green color reaction will occur in the presence of blood. Given a sufficient blood sample in the questioned stain, Hemastix® strips work well. Hemastix® suffers the same fate as many presumptive tests — there are a number of false positives. In fact, some gunpowder residues have been known to cause a false positive with Hemastix®.

If you are working with trace amounts of a suspected bloodstain, the other reagent tests are probably best. In these instances the analyst folds a small section of clean filter paper, creating an edge or point. This point is rubbed against the stain or area in question. An alternative approach is to moisten this edge or point with saline solution, particularly in instances of very dry stains, and then rub the moistened area against the stain. The analyst then applies the particular reagent as required.

Phenolphthalein solution is another standard approach. The analyst requires the active reagent, ethanol, and hydrogen peroxide. After sampling

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of the stain, the filter paper is dampened with a drop of phenolphthalein. The analyst then adds a drop of ethanol, followed by a drop of hydrogen peroxide. An immediate purple-pink color reaction will occur in the presence of blood.

Leucomalachite green acts both as a presumptive test and as an enhancement tool. Used as a presumptive test, the reagent includes a mixture of sodium perborate, leucomalachite green, glacial acetic acid, and water. As with the other tests, several drops are applied to the test swab or filter paper, followed by a few drops of hydrogen peroxide. A positive test results in an instantaneous blue-green color.

All of these chemicals may represent health risks. Before using any method, the analyst should seek and receive instruction in their usage from the supporting crime laboratory.

In the U.S. the orthotolidine test, a derivative test of benzidine, is still in use. Although it was widely accepted and is easily completed, it has clear health risks identified with its use.[2] Other techniques are available that do not pose the same risks. This test is not appropriate for scene examinations.

Another advancement in on-scene stain identification is the recent development of a human-specific blood test. The test, called *OneStep ABAcard HemaTrace*, is intended for both lab and scene use. It requires no refrigeration and no reagent preparation. It is claimed to be highly sensitive and requires only a small sample. This type of test is far more accurate and specific than the presumptive tests and will likely replace them in the near future.

Enhancement Techniques

The specific enhancement techniques we will discuss include luminol, fluorescein, leuco crystal violet, and leucomalachite green. Other enhancement methods available to the analyst include Amido black, DAB, and TMB. All of these chemicals allow for better visualization of bloodstains not only for the bloodstain pattern analyst, but also for the fingerprint and tool mark examiner. If lacking experience in the use of these techniques, check with a local crime laboratory. They are likely to have considerable experience in preparing and safely using them.

Many of these chemicals react to peroxidase activity in the heme of the red blood cell.[3] Unfortunately, they also react to other peroxidation changes in many substances. These substances include vegetable matter and phosphates present in detergents, bleach, and other common household chemicals. Before accepting the enhancement product, the analyst must consider any enhancement reaction within the context of the entire scene and all evidence.

Luminol enhances our ability to see what are oftentimes invisible traces of blood. In that regard, it is a valuable tool. The overall recipe for a luminol

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solution includes sodium perborate, sodium carbonate, 3-aminophthalhydrazide, and distilled water. The ratios for the mixture are, respectively, 0.7, 5, and 0.1 g dissolved in 100 ml of water.[4] In recent years commercially prepared kits have become more widely available and relatively inexpensive.

Luminol reacts to the hemoglobin present in the red blood cells.[5] The result is a chemi-luminescence, or creation of light, which appears blue-green. This is an important factor to consider: that which the analyst observes is a light source. Obviously, light sources have boundaries that are measurable, but it is unlikely that clear specific boundaries exist (e.g., sufficient to define an individual spatter stain's impact angle). Overall dispersion and general dimensions of patterns and smears will be obvious; beyond that, evaluations are speculative.

Because the reaction is light producing, the analyst must observe the area or object of concern in darkness. Outdoors, luminol works effectively at night; inside, the analyst can darken the room by turning off light sources and covering all windows.

Some of the benefits of luminol include:

- It is applied easily.
- It is noncorrosive and nonstaining.
- It is relatively nondestructive to blood with regard to ABO typing.
- Methods exist to photograph the reaction.[6]

Luminol's disadvantages are:

- It reacts to some metals, vegetable peroxidases, and chemicals including bleach.
- The method demands darkness.
- Interpretations are limited.[7]

The following examples illustrate the possible uses of luminol:

- Depicting or discovering light smears or wipes present on floors and walls
- Following bloody trails from the scene of a murder to indicate direction of flight by the murderer
- Enhancing patterns present on clothing
- Checking scenes of suspicious disappearances, even years later, for indications of invisible blood traces left by clean-up actions

Although luminol reacts to many things, Doug Perkins, a criminalist with the Oklahoma State Bureau of Investigation, offers the advice that with

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sufficient practice and experimentation the analyst can often identify such false-positive reactions. Perkins looks at three areas when evaluating a luminol reaction: color, intensity, and duration.[8] He then compares each with his knowledge of the reaction evident in known blood samples.

Bevel also feels that luminol is an outstanding investigative aid, but that it is often misused by those with an insufficient training foundation. Before attempting to use luminol in a case circumstance, the analyst should experiment with it and become familiar with the ranges possible in the reaction. Due to 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.

Another concern for the analyst is documenting the luminol reaction. In the late 1980s Gary Rini 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 could not tell exactly where the reaction occurred on the evidence. Using paint-with-flash techniques similar to those used in spelunking and outdoor crime scene photography, Rini and Gimeno produced images that include both the luminescence and the evidence item. Their efforts are documented in two articles published in the *Journal of Forensic Identification*.[9,10]

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 exposure, but may expose the negatives for as long as 15 min depending on 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. (Color Figures 12 through 15 show examples of luminol photography using this technique. Color Figure 16 illustrates an additional technique developed by the Larimer County Sheriff's Department, Colorado, which uses luminous tape and a clear ruler to ensure a scale is evident in the photograph.*)

Leucomalachite green offers an advantage over luminol, because it gives a color reaction. The results are observed, measured, and documented more easily than luminol reactions. It is prepared in a solution and sprayed on the surfaces in question. Stains that react to the solution discolor green, allowing better visualization.

* Color Figures 12 through 16 follow page XXX.

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Leuco crytsal violet (LCV) is an enhancement method preferred by fingerprint and footwear examiners. LCV reacts with hemoglobin and in its presence turns a purple or violet color.

The reagents required to prepare an LCV solution are

- 10 g 5-sulphosalicylic acid
- 3.7 g sodium acetate
- 1 g LCV
- 500 ml of 3% hydrogen peroxide

The 5-sulphosalicylic acid is dissolved in the hydrogen peroxide. The sodium acetate is then added and dissolved. The leuco crystal violet then follows. Once dissolved, the solution may be stored for some period in dark glassware. At the scene the solution is lightly sprayed on the suspect area. The reaction should be nearly instantaneous.

Another method of blood enhancement that may ultimately replace luminol is fluorescein. This method eliminates the need for total darkness but requires the use of an alternate light source (ALS). The technique works best when one operates the ALS at the 445- to 450-nm range. Before application of fluorescein, the substrate in question is 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 fluorescein reaction.

The fluorescein solution is mixed in accordance with the following formula:

- 25 cc distilled water
- 2.5 g sodium hydroxide
- 0.25 g fluorescein
- 0.5 g zinc

The analyst mixes the water, fluorescein, and sodium hydroxide together then adds the zinc, allowing the mixture to set until nearly clear. The liquid is poured off and the solution is mixed 1:80 in distilled water and applied with a spray delivery system. A solution of 3% hydrogen peroxide is then sprayed on the surface as a catalyst. Under ALS, latent and occult blood traces will fluoresce blue-green. Unlike in luminol reactions, the analyst will find it is much simpler to photograph a fluorescein reaction, because the light of the ALS is usually sufficient to allow the use of a digital camera.

Whenever working with chemical enhancement tools, the analyst must consider proper safeguards. Disposable protective clothing and breathing protection are necessary when spraying chemicals in any location. Remember, many of these chemicals are carcinogenic or suspected to be carcinogenic.

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Bloodstain Pattern Photography

Far too often crime scene photographs of bloodstain evidence are meager, insufficient in detail, and generally lacking. Simply put, photographers often 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 not only to the bloodstain pattern analyst, but also to 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 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 photography 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 some of the individual spatter used in the determination.
- Use Toby Wolson's *roadmapping* method or a similar procedure.[11]

Documenting the scene is important no matter what the nature of the crime. Whether bloodstains are involved or not, the crime scene technician should photograph the scene immediately upon arrival. As a general 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

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Figure 9.1 An overall photograph that establishes the presence of an arterial spurt on a bathroom wall. The specific stain is not clear, but the photo allows the viewer to understand its relationship with the scene. An intermediate landmark (the large smeared area) will assist the viewer in this understanding (see Figure 9.2). (Photograph courtesy of Tom J. Griffin, Bruce Goodman, and Ken VanCleave, Louisville Police Department, Colorado.)

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 document the scene as found and eliminate the destruction, addition, loss, 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 an evidence-establishing shot and close-ups 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, Figures 9.1 through 9.3 are scene photographs that take the viewer from an overall perspective to a close-up view of the evidence of concern. In the end, the viewer realizes where the arterial spurt in question is in relationship to

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Figure 9.2 An evidence-establishing shot. This photograph shows a closer view of the bathroom wall using the large wipe and swipe as a landmark. The viewer can more clearly see the location of the arterial spurt to the right of the smeared area, but still not in sufficient detail (see Figure 9.3). (Photograph courtesy of Tom J. Griffin, Bruce Goodman, and Ken VanCleave, Louisville Police Department, Colorado.)

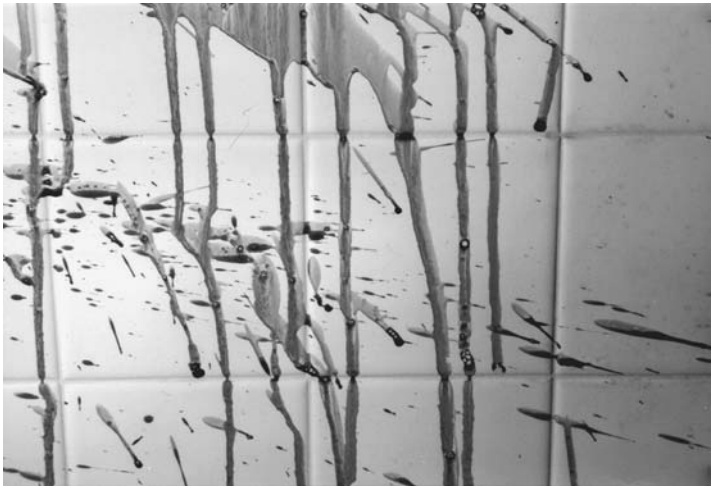

Figure 9.3 An evidence close-up photograph without a scale. Individual stains in the arterial spurt are much clearer. Directionality of the stains is evident. Additionally, the closer view allows us to see air bubbles in the stains — an important feature that indicates the arterial spurt was associated with a lung or airway injury. (Photograph courtesy of Tom J. Griffin, Bruce Goodman, and Ken VanCleave, Louisville Police Department, Colorado.)

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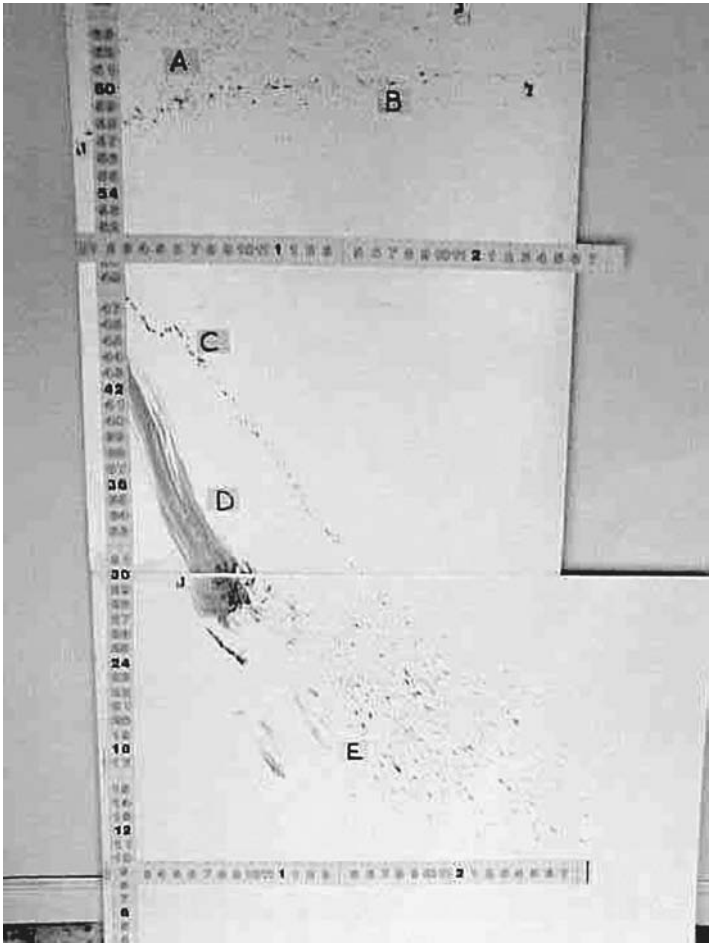

Figure 9.4 An overall photograph, which orients the positions of the various stains to the scene. By themselves such photographs rarely provide the detail necessary for proper bloodstain pattern analysis, but they are important to document the overall scene.

the bathroom wall. 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 complete condition of the item.

As discussed, the photographs should lead the viewer from the overall picture to the detail. Figures 9.4 through 9.9 depict a classroom exercise of what the basic objectives of documentation should achieve.

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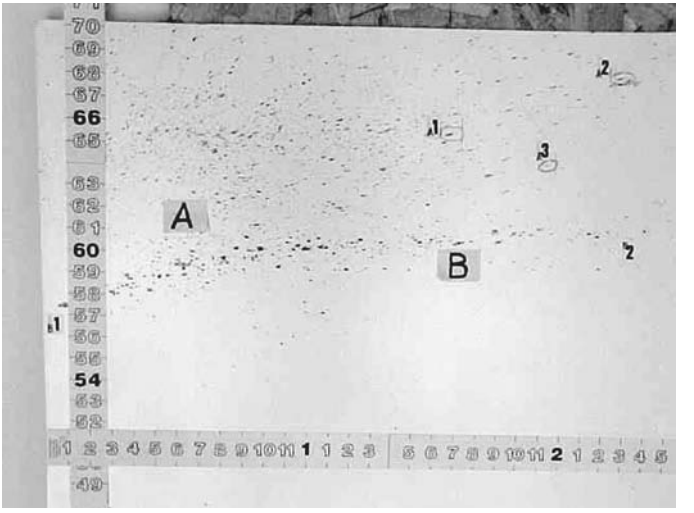

Figure 9.5 An overall photograph of a specific pattern, Pattern A, which is a spatter pattern. Similar to a scene overall, the pattern overall identifies the extent of a specific pattern.

Figure 9.4 is the overall photograph of a specific wall or area. It defines five distinct patterns of interest. These patterns are labeled A through E. One should clearly see the orientation of one pattern to the others and to the scene in this photo. Figure 9.5 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. Evidence close-ups will allow us to see that detail later. Figure 9.6 is an overall pattern photograph of Pattern D, a swipe mark, as well as a cast-off pattern labeled C. Once again, the purpose is to document the entire pattern as it exists. Figures 9.7 and 9.8 are examples of the detail of spatter from Pattern A. Note that each is annotated with a plumb line and a scale of reference. With the XYZ information obtained at the scene, these photos could be evaluated using a program such as *Backtrack Images® or Backtrack/Win®*. Figure 9.9 is a close-up of detail present in Pattern D, specifically the presence of the bifurcations. This detail is important because 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, because it makes it difficult to identify a particular stain and its proper orientation.

Having discussed the general requirements for photography, let's 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

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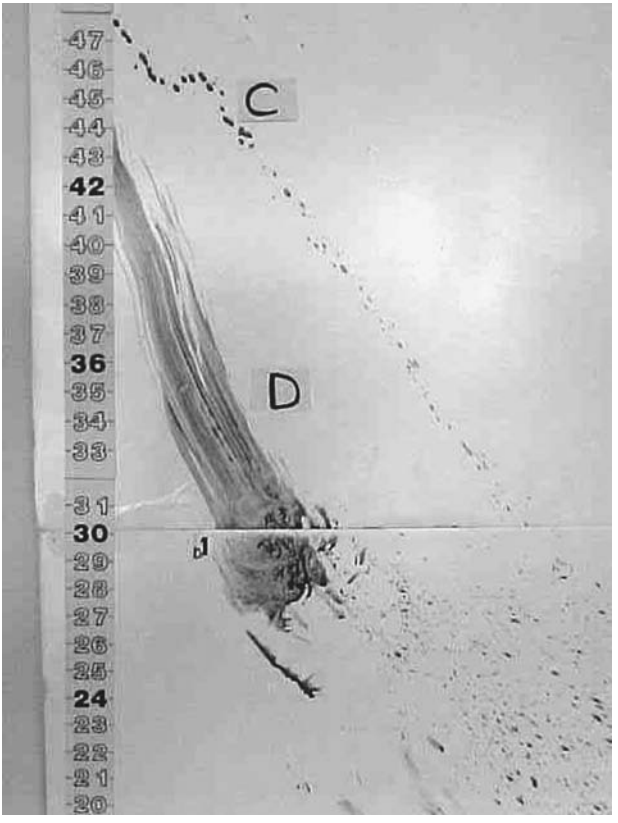

Figure 9.6 An overall pattern photograph of Pattern D, a swipe mark.

a "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. Afterwards, take any and all steps to protect the pattern from physical damage.

If the analyst follows our previous documentation advice, then all major pattern groups in the scene will have some identifiable number or letter. The next step of photography is to document these major patterns. As noted, the photographs should include an evidence-establishing shot. This photograph has some identifying marker so that similar-looking patterns can be distinguished from each other. The establishing photo clearly places the item or pattern in relation to some other identifiable object in the scene. In 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 this photo, patterns lose relevance, particularly when viewed by others later in the investigation. Consider Figures 9.10 and 9.11. Without the establishing shot (Figure 9.10) the evidence close-up photograph (Figure 9.11) tells the

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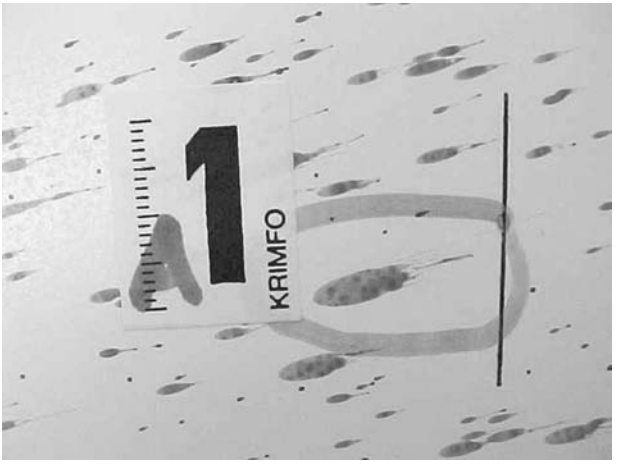

Figure 9.7 Close-up photograph of Stain A1, from Pattern A, the spatter pattern. These types of photos provide specific detail from the pattern or stain, allowing actual analysis.

Figure 9.8 A close-up of Stain A2. The label evident in this pattern is also evident in Figure 9.5, which allows one to orient the position of this stain to the overall pattern.

viewer little with regard to the location of the item in the scene. The same is certainly true for close-up photographs exposed after collection of the evidence. The pattern evident in Figure 9.12 means little to the viewer without the accompanying photograph, Figure 9.13, that shows its location on the murder weapon.

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Figure 9.9 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 part of the swipe allow the analyst to identify the source of the pattern as hair or a hair-like object.

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 examples of stains that might be of interest. Macro photographs or close-up photographs of evidence are taken with the lens inches away from the stain, not feet away. 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 from every conceivable angle. Place the film plane parallel with the plane you are photographing. Once that's done, fill the viewfinder with the subject. 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 point of origin determinations are necessary, then photograph some of 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 point of origin determination.

Close-up photographs of evidence 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 (Figures 9.14 and 9.15).

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Figure 9.10 Another example of an establishing shot. In this instance we can read the label of the stain in question (Stain 3A) and see its position near the door above the table.

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" or "Up," which is necessary if the analyst chooses to align the template scale with the droplet's axis. These templates work well in conjunction with the roadmapping method.

Roadmapping is the most effective method of completing photography documentation of bloodstains. Developed by Toby Wolson, a criminalist with the Miami-Dade Police Department, Miami, Florida, the method is effective but 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, identify each major stain group with a label, either a letter or number (e.g., Stain Group A) (Figure 9.16). Individual stains or smaller patterns of interest within this larger pattern are given an additional identifier such a 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.

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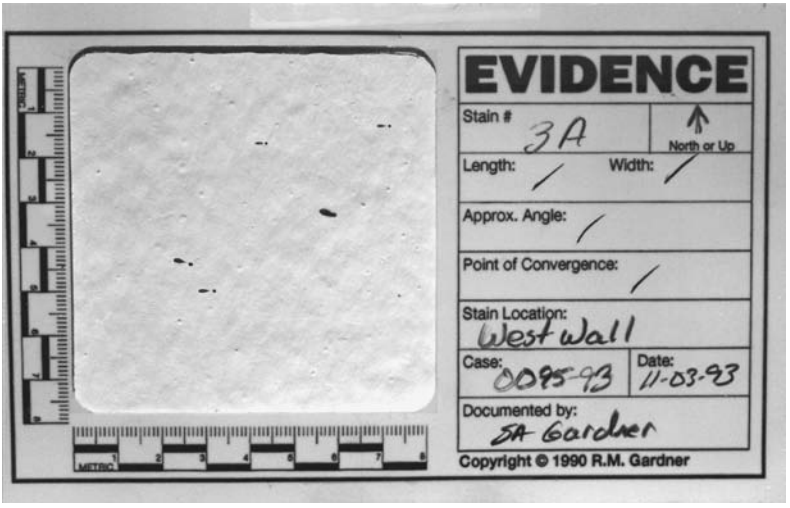

Figure 9.11 A close-up photograph of the stain in Figure 9.10. Without the accompanying establishing photograph, it would be difficult for the viewer to understand this spatter's relationship to the scene.

Adjacent to the pattern, the analyst introduces large reference scales to the surface involved. These scales are commercially available from forensic sources. For instance, for stains on a wall the analyst places the scales along the side of the wall and above or below the stains. If possible, the pattern should be outlined by the scales.

The analyst then photographs the overall surface including the scales. The stain labels should be readable in these shots. The analyst then moves in to photograph 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 on the wall or surface the analyst is looking. These labels are the "signs" on our roadmap. They preclude us from being lost (Figure 9.17). 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. Figures 9.18 and 9.19 document the spatter observed in Figure 9.17, 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 important information. Figures 9.20 and 9.21 are examples 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

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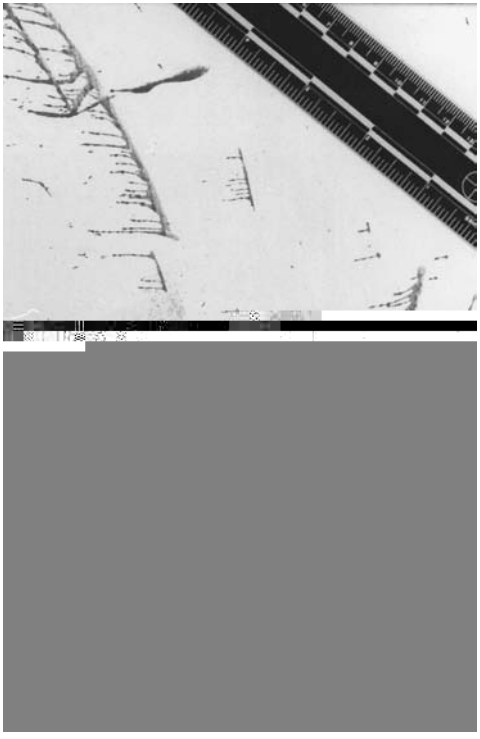

Figure 9.12 An interesting pattern resulting from a beating death. The scale indicates the size of the stains, but where are they found and what relationship do they hold? Without an accompanying evidence-establishing photograph, Figure 9.13, the viewer has little with which to judge the significance of the pattern. (Photograph courtesy of Donald R. Schuessler, Department of Public Safety, Eugene, Oregon.)

viewer from an overall view, to the pattern, 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 also for later documentation of individual items of evidence. For example, Figures 9.22 through 9.24 show documentation of a bloodstained shirt using this method.

Another method used for photographic documentation of small spatter stains is the introduction of hole reinforcements into the picture. After the analyst has taken standard evidence-establishing and evidence close-up photographs, self-adhesive reinforcements are placed around individual spatter. Then another evidence close-up photo is taken. The reinforcements make each stain more obvious in the photograph (Figure 9.25).

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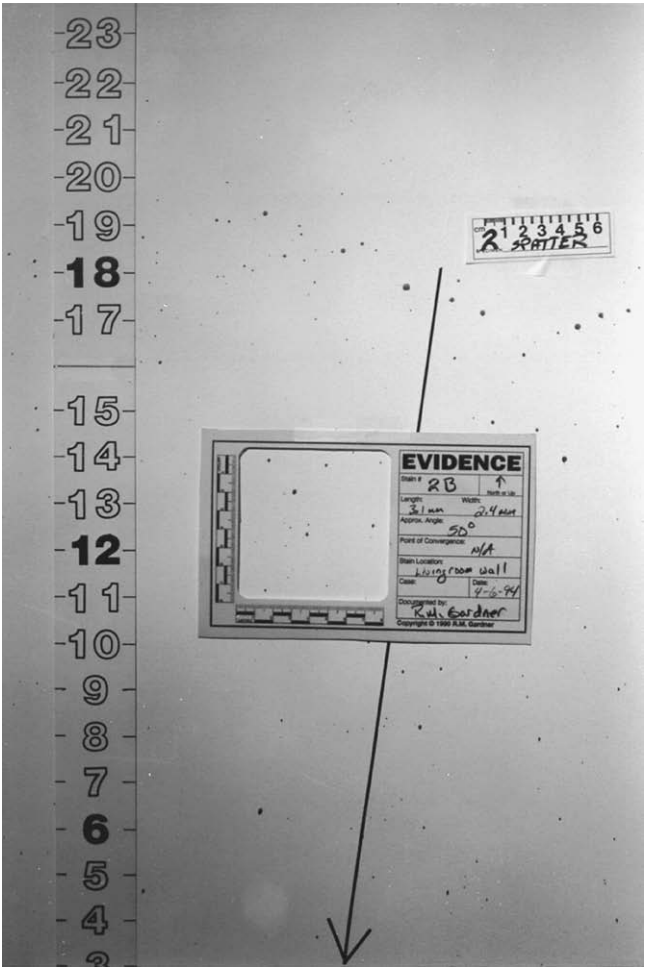

Figure 9.14 Using the bloodstain photographic template to document evidence. In this instance the photograph is that of an intermediate establishing shot. When used to shoot evidence close-up photographs, such as Figure 9.15, the template is a subtle reminder to the analyst to fill the frame of the lens with the image. It also allows for administrative data to be included in the photo with the stain.

bloodstained scene. It serves as a functional method for documenting the scene *in situ*. A quick, nonintrusive 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 initial scene photographs, video often clears up specific concerns regarding scene integrity issues.

After scene processing is complete, the video camera is also effective for overall documentation purposes. If the analyst has used Toby Wolson's road-mapping techniques, the scales and "signs" are already in place. The analyst

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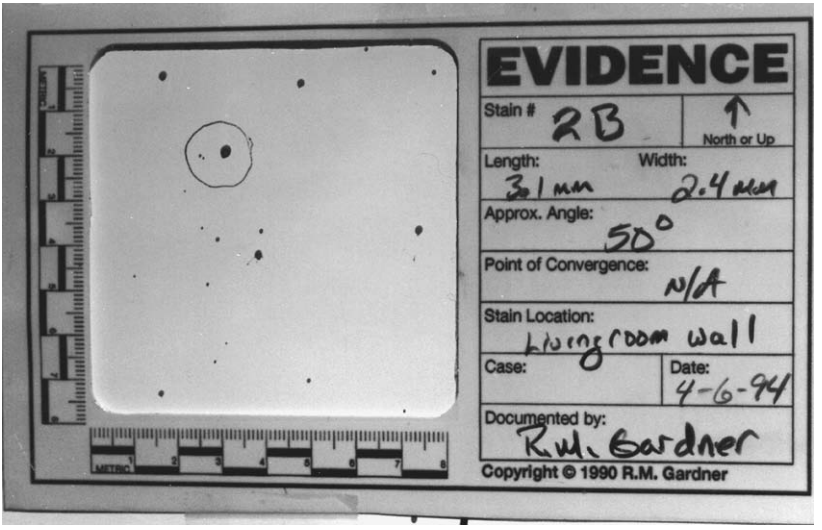

Figure 9.15 A close-up photograph of the spatter in Figure 9.14. In this instance we include measurements of the individual spatter stain (circled) and indicate its apparent impact angle.

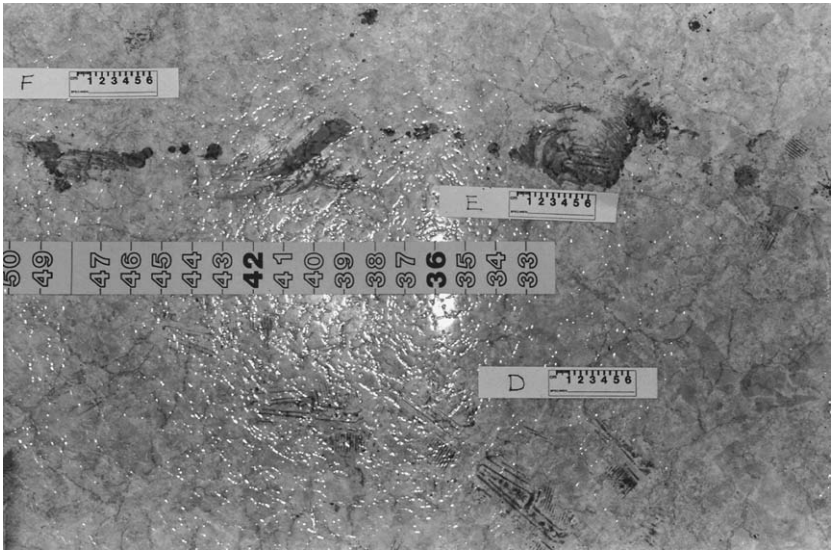

Figure 9.16 The roadmapping technique. In this photo we have an intermediate establishing shot, the intent of which is to show the relationship of Stains D, E, and F to one another. The large scale lets the viewer know that the stains are some 36 in. from a wall or similar juncture.

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Figure 9.17 The typical close-up photograph found in most documentation files. Although the analyst should expose 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. The viewer is "lost" in the scene with no means to associate the picture to its origin. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida.)

merely "walks" the viewer through the scene, showing the relationship of the specific stains to other items of interest. Combined with the 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 use at the scene. During videotaping, 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, and help the trier of fact to understand the overall circumstances of the crime.

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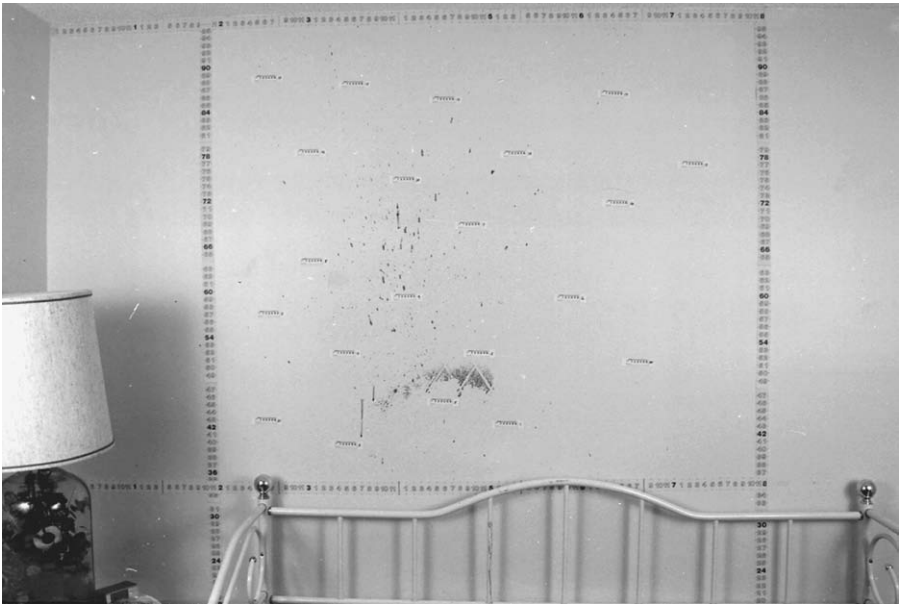

Figure 9.18 A roadmapping example. Using the stain from Figure 9.17, this series demonstrates the function and utility of roadmapping. In this photograph we have an overall perspective that includes scales of reference, furniture items, and a roadmap label. Although perhaps difficult to read in this reproduction, the individual stain labels were readable in the actual photograph. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida.)

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 the relationship of one stain to another or correlate a stain to its physical surroundings. The level of detail necessary for bloodstains in a sketch depends on the needs and desires of the analyst. We feel that all major patterns should be addressed in some fashion. This may only require the inclusion of the pattern label (e.g., Stain A) at the general location in which the pattern was found. This concept 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 relates one stain pattern to the location of another (Figure 9.27).

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

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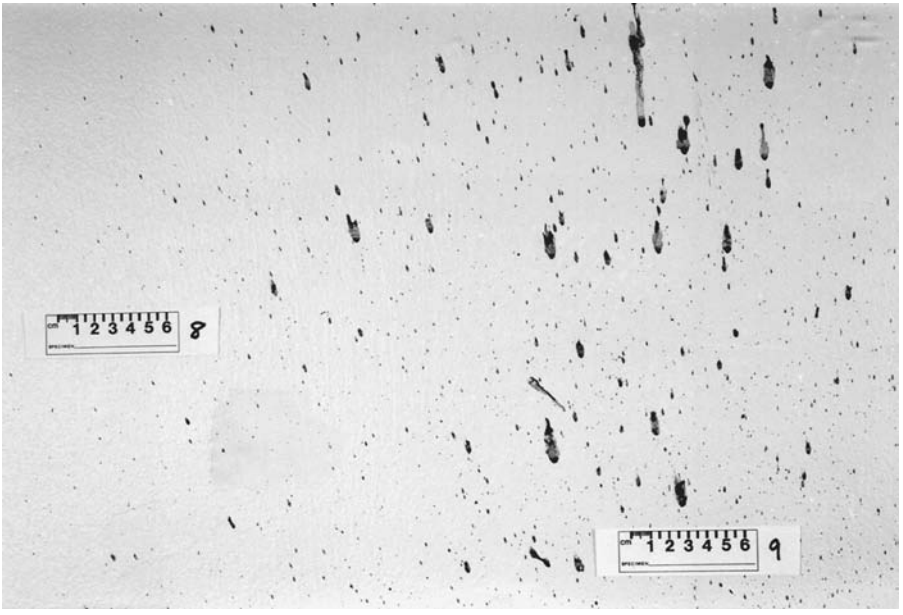

Figure 9.19 A close-up photograph of the spatter in Figure 9.17. Using two labels (8 and 9) in conjunction with Figure 9.18, the viewer is able to recognize where in the scene the spatter is actually located. The roadmapping method moves the viewer from the overall perspective of the scene to the pattern and then to the detail in the pattern. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

of stains of importance. Such sketches can include freehand drawings of patterns (e.g., patterns on clothing) or tracings of a given pattern.

Freehand drawings may or may not be to scale, depending on the needs of the analyst. The analyst should highlight all observable characteristics. *in situ* evaluation is truly the best evaluation circumstance. While making the sketch the analyst may see detail that is not discernible in the crime scene photographs. For this reason Epstein favors the use of detailed drawings when evaluating clothing. He feels this forces the analyst to look more closely at the evidence.[12] In whatever fashion it is used, the freehand sketch becomes an integral part of the analyst's crime scene notes.

Another method of sketching is the tracing of patterns. The analyst simply tapes tracing paper or an acetate sheet over the stain or pattern in question and traces its characteristics. This allows the analyst to create full-size reproductions, which may be of some use. Unfortunately, depending on the nature of the pattern, tracings can be very time consuming.

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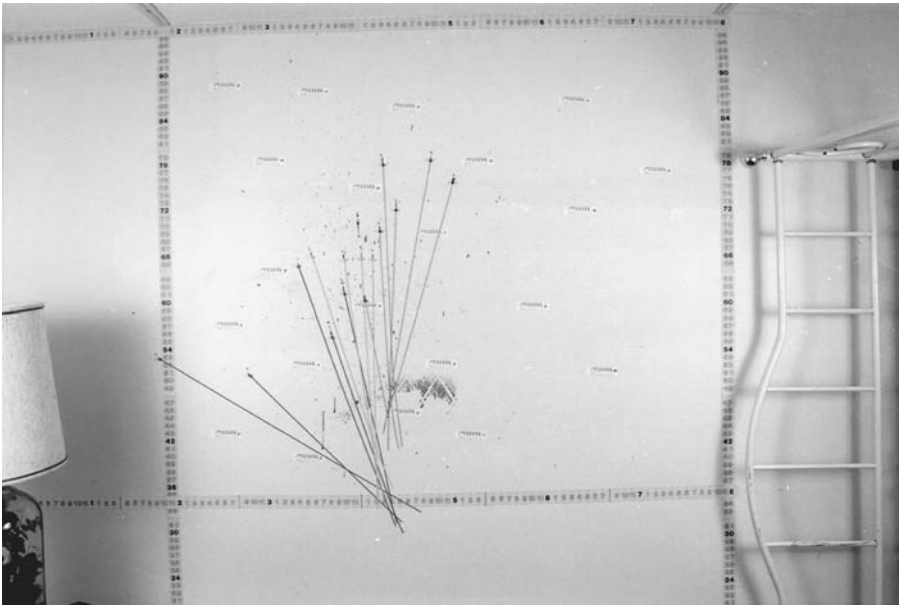

Figure 9.20 A continuation of the roadmapping method. This time the photographer introduces graphic tape to show a point of convergence for the spatter involved. For clarity, the headboard was removed and set to the side. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida.)

Written Reports

Photographs, sketches, and videotapes 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 both 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.

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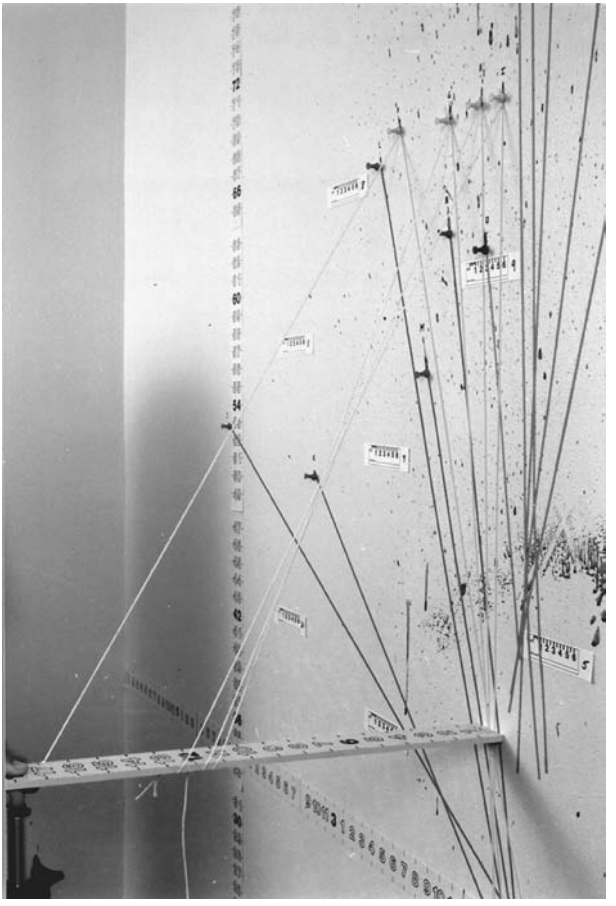

Figure 9.21 Another example of roadmapping combined with the "stringing" method. This combination allows the viewer to see the likely point of convergence (as shown by the graphic tape) as well as the probable point of origin (as indicated by the strings). (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida.)

Each major pattern or stain group is 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 a spatter pattern present on the wall adjacent to the headboard.

This categorization should not be speculative in any way. For instance, one would not want to categorize such a pattern as expiratory 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:

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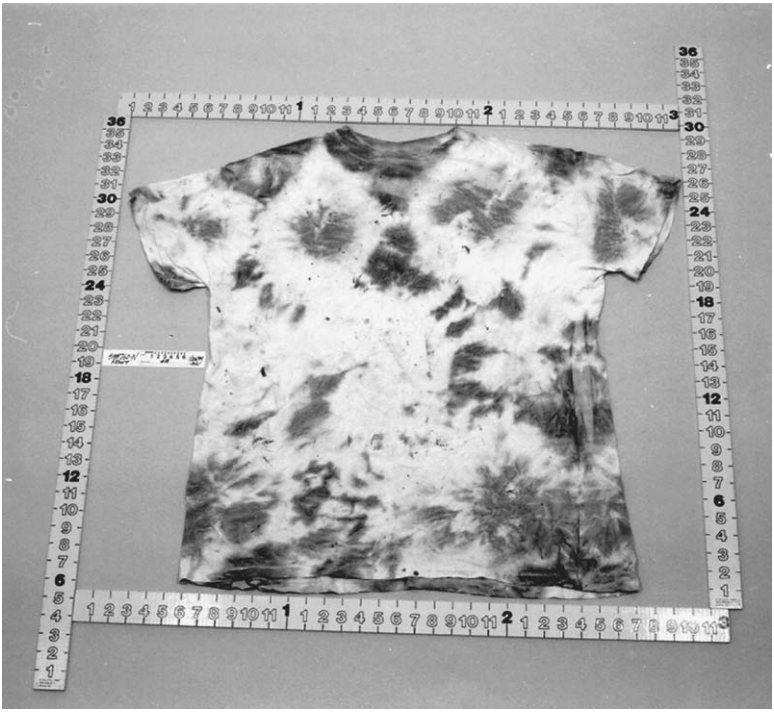

Figure 9.22 Roadmapping is just as effective for documenting items of evidence after collection. In this instance we have an initial photograph of the overall item, framed by the large scales. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

The pattern is a spatter pattern. The majority of the stains are circular in nature with very few elliptical droplets. The pattern fits the category of a medium-velocity stain (i.e., spatter stains between 1 and 4 mm in diameter). The majority of spatter present in the pattern are actually less than 2 mm in size.

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. Nor is any specific radiating effect evident in the photograph.

There are no indications of cast-off patterns associated with the pattern.

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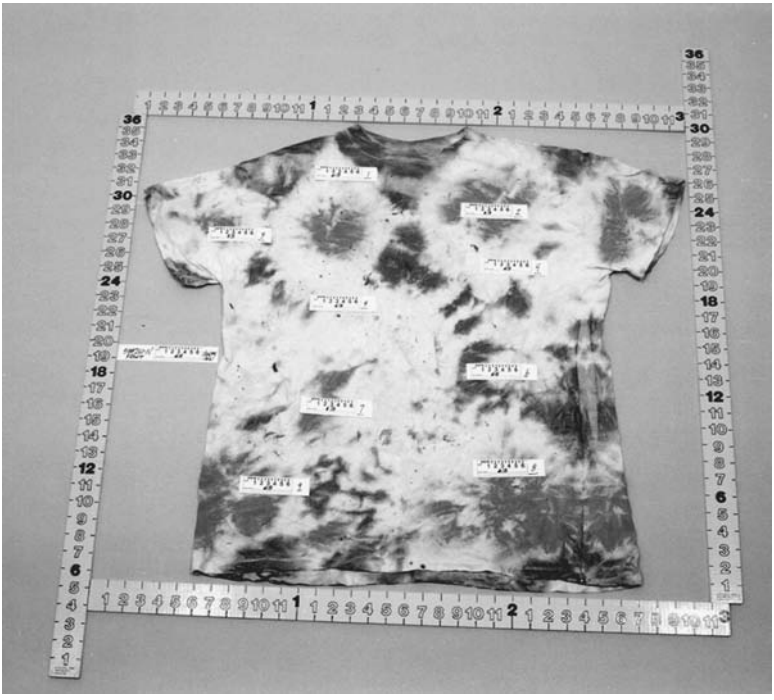

Figure 9.23 In this second photograph of the shirt, an establishing shot, labels are introduced to identify the specific stained areas on the shirt. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

There are generally two approaches as to where in the report the analyst should present conclusions. Judy Bunker asserts the conclusions should be presented at the end of the report in a conglomerate fashion, rather than being included with the description of the stains. The following is an example of a conclusion sheet from Bunker's advanced course:

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.
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.[13]

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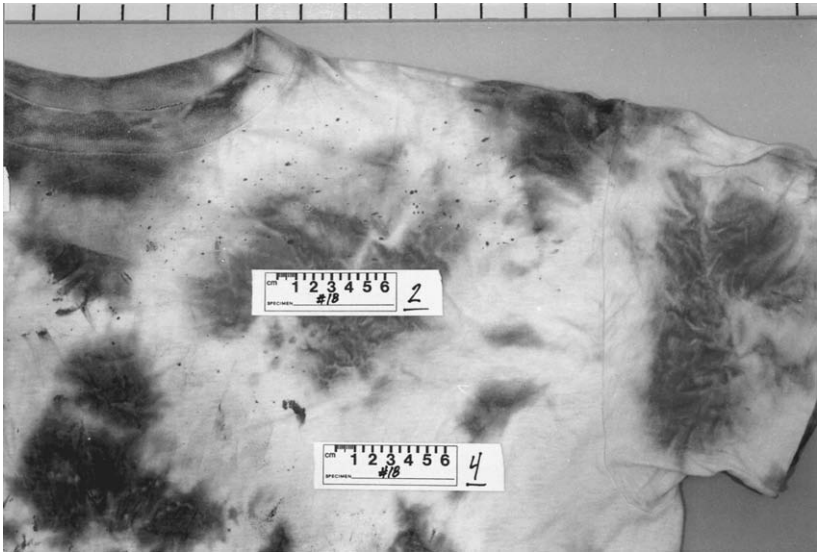

Figure 9.24 An evidence close-up photograph of Stains 2 and 4 on the shirt. By referring to Figures 9.22 and 9.23, the viewer could easily determine the stain locations even if the collar were not evident in the photograph. (Photograph courtesy of Toby Wolson, MS., Miami-Dade Police Department, Florida. From *J. Forensic Identification*, Volume 45, Number 4, August 1995.)

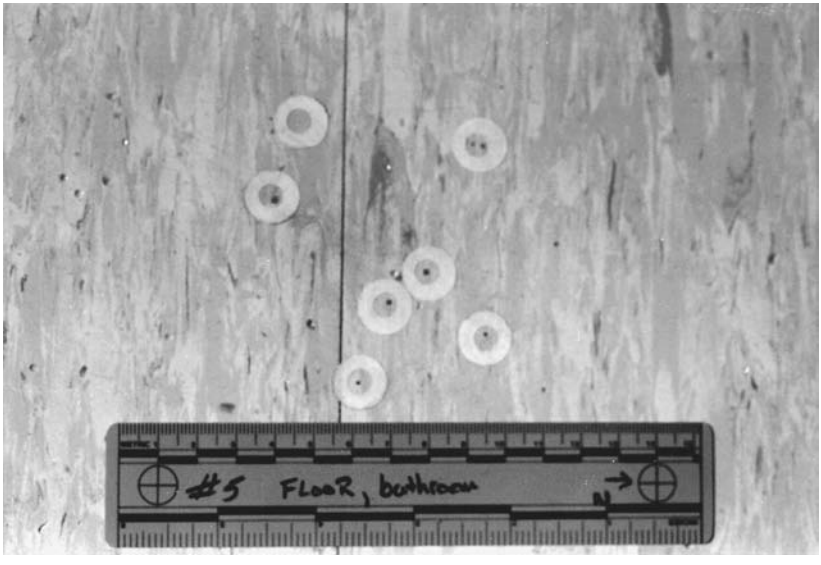

Figure 9.25 The use of self-adhesive hole reinforcements in a crime scene photograph. The reinforcements highlight the specific locations of very small spatter on the floor. In instances of small spatter (e.g., gunshot spatter or expiratory blood) the reinforcements make it easier to locate the spatter in the photograph.

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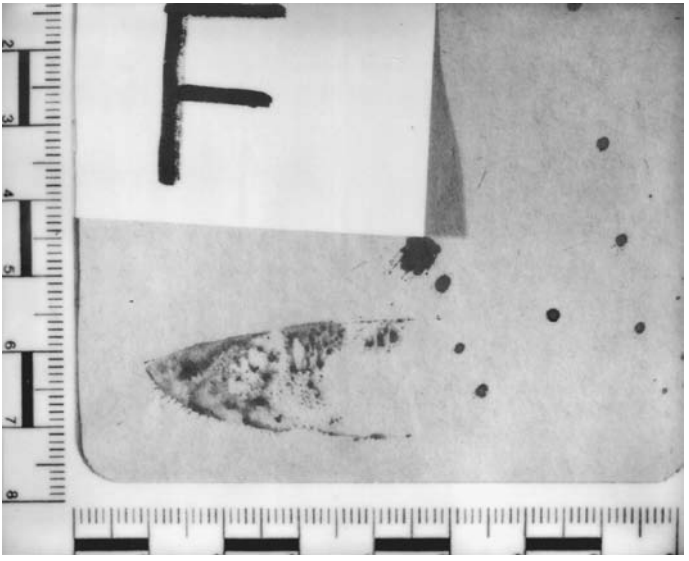

Figure 9.26 Using a commercial instant camera with a 1:1 copy stand, quality close-up photographs are possible. Although these cameras cannot replace 35-mm or larger format cameras, they do ensure that the analyst leaves the scene with all critical stains documented in some fashion.

Another approach is to simply include a brief conclusion regarding the individual stains after their 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 which occurred in the vicinity of the bed mattress. The small size of the stains suggests a strong forceful impact. No other correlations are possible at this time.

Obviously, such conclusions should be limited to what that particular stain details for us. Correlation of one stain to another and conclusions drawn from them should be presented somewhat as Bunker describes — either as a final concluding statement or in the body of the reconstruction itself.

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. We have underlined some of the detail that we feel comprises these specific observable characteristics. Without this type of detail it is difficult for analysts to support why they reach the conclusions they do.

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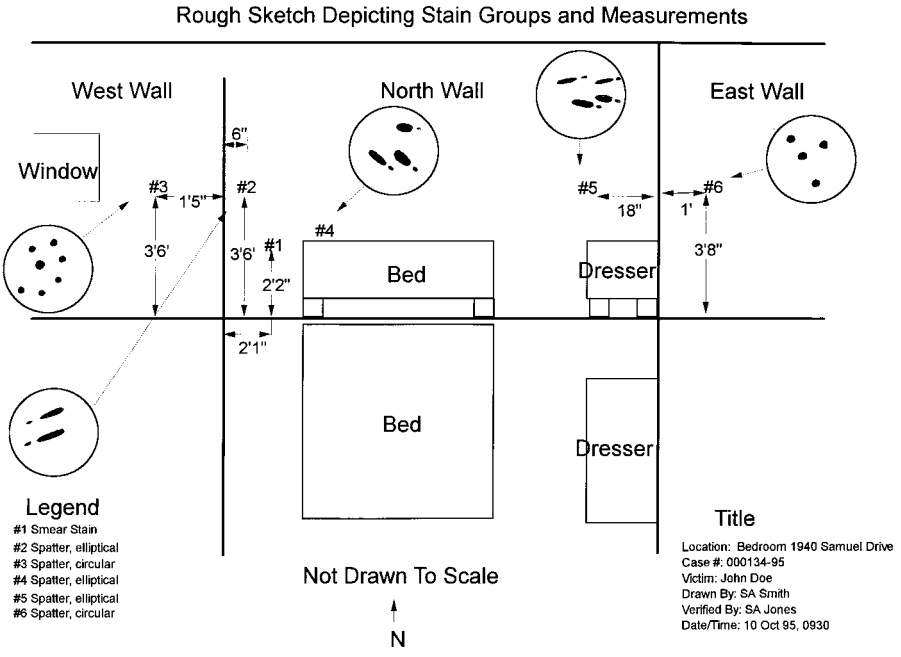

Figure 9.27 A cross-projection sketch allows the viewer to consider evidence present on various surfaces in the scene. For example, the positions of Stain Groups 2 and 3 indicate a common source of origin. This relationship might not be immediately evident to someone reading the report without the cross-projection sketch.

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 impact spatter, 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.

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, while present on either the bed or the 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.

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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.

Although not pure in origin (e.g., not all blood) it represents a flow of some nature. The stain 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.

The upper right-hand section suggests linear features that 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 drips or drip pattern satellites are 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 then no further action occurred to that side.

A Pattern Transfer Description/Conclusion

Stain Group 7: This group includes numerous pattern transfers on the pillow case. The entire pillow case 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 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 pillow case 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(s) came in contact with the pillow case. The manner of these sets of stains indicates a random application of the object(s) to the pillow case. There are many more linear features

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present on the pillow case, but none provides specific characteristics beyond indicating an object with a bloody edge was in contact with the pillow case.

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 with.

A Mixed Pattern Description/Conclusion

Stain Group 8: This group consists of a saturation stain on the upper sheet of the bedding. It includes pattern transfers evident to the left of the saturation stain and spatter evident to the right.

The pattern transfers are linear with dual boundaries indicated, similar to those found on the pillow case. The linear stains range from a few mm in length to 11 cm. The application appears less random than that found on the pillow case, 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 pillow case. 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 is much heavier here. 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 pillow case 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 makes the point, "This is a report which will be examined, reexamined, and dissected by others."[14] If you are not confident you can support your findings, then do not include them. To support the findings, the analyst must describe every important characteristic evident at the scene.

Summary

Documentation of bloodstains at the scene is truly an important function. Without quality documentation, the analyst may doom any subsequent analysis to failure.

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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, to include their limitations.

Graphical documentation in the form of sketches and photographs is equally important. They must clearly show stain detail and define the location of the stain in the scene. Without details about stain location, it is difficult at best for the analyst to make any rational decision about the overall reconstruction.

Written documentation is the true backbone of the overall documentation effort. In Chapter 10 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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Documenting the Reconstruction of a Crime

10

Just as the documentation of bloodstain patterns requires specific effort, a reconstruction report requires a similar level of effort from the analyst. For purposes of the reconstruction report, however, there is a twofold problem. First, the reconstruction is a compilation of information from various sources and reports. It is not based on a single individual's efforts. The analyst must have a thorough understanding of these reports and must interrelate specific facts from all of them in order to reach a reconstruction conclusion. Second, the reconstruction derives its actual form through a reasoning and logic process; a reconstruction is very much a mental product. Unlike physical evidence, it is often far more difficult to point to its subtleties. For this reason it is easy for the analyst to lose focus and often difficult for others to grasp the analyst's underlying decision-making process.

In this chapter we will present several methods for preparing the crime scene reconstruction report and provide guidelines to consider when developing and executing experiments and re-creations in support of a reconstruction attempt.

The Reconstruction Report

In effect, the reconstruction is a word puzzle derived from the total investigative report. This puzzle is unraveled in the mind of the analyst and then put to paper. If others are to believe its final form and conclusion, they must be confident they understand how the analyst arrived at the individual reconstruction decisions for the conclusion.

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Far too often in investigative reports, this final form is a simple statement such as:

> Smith raped Jones at knife point, resulting in two stab wounds. At the conclusion of the assault, Smith shot Jones while she was lying on the floor.

Although such a concluding statement may well be accurate, it leaves the reader sorting through every document related to the report in order to try and understand how the investigator reached that particular conclusion.

Even after reviewing all of the related documents, the "how" is not always evident. Reasoning is an individual mental process. We can never be confident that the reader will see the same significance in each piece of information or put the same bits and pieces together in the same manner. Thus the reconstruction report must elaborate on the analyst's reasoning and lead the reader step by step through that process. Only then can the reader of the report properly evaluate the conclusion and determine if he or she agrees or disagrees.

Certainly if there is disagreement both parties can then point to specific issues and recognize at what point their opinions diverge. What should not occur, although it often does, is an off-the-cuff dismissal of an opinion regarding some event segment. If two forensic experts are viewing the same evidence, then there is little rationale for completely polarized viewpoints.

The discussions in this chapter are applicable to both bloodstain pattern evaluations and generic reconstruction of crimes. Remember that any bloodstain pattern analysis conclusion is nothing less than a limited crime scene reconstruction. This is true because the bloodstain pattern analysis conclusion seeks to:

- Define specific actions that caused certain stains
- Sequence those actions and events
- Consider whose blood is involved, which will hopefully identify who took the action

Our discussion of event analysis in Chapter 2 provides a format for preparing this conclusion. The crime reconstruction report, however, considers more than just the blood evidence in determining these conclusions; it must incorporate all of the forensic information in its findings. It should consider and reference the decisions and reports of other forensic experts (e.g., the pathologist, serologist, and tool mark examiner).

Using event analysis as a backdrop, as a minimum the reconstruction report should identify the events and event segments. For each event segment the report should list the critical facts that support that segment. These facts

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may include physical evidence, testimonial evidence, and other related conclusions. Because the conclusions stem from varying sources, the reconstruction report should also include some method of cross-reference. This will allow the reader to seek out specific cites within the other documents. A basic format might look something like this:

EVENT #1
  Event segment #1a
    Supporting evidence Cross-reference
  Event segment #1b
    Supporting evidence Cross-reference

In this chapter we will discuss three report formats that serve the analyst's needs. All of them use this basic format, but with different levels of detail and in slightly different fashions. These three formats are

- Event analysis — outline format
- Statement comparison to event analysis
- Event analysis — narrative format

Event Analysis in Outline Format

For reconstructions using event analysis in outline format, each major event and event segment is described. Specific facts supporting a given event segment are included, along with a cross-reference. For purposes of this example, the following reports were utilized:

CS — Crime scene report
MR — Medical report (from emergency room)
BP — Bloodstain pattern report
VS — Victim statement
SR — Serology report

In the following reconstruction, note that the capitalized letters represent the event, the numbers represent the event segments, and the lowercase letters represent the supporting evidence. The number that appears with the abbreviation in parentheses refers to the page number of that report.

Events and Event Segments

A: Disturbance occurs within the bathroom. No major bleeding injuries occur here.

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1. Beer bottle broken in the tub; probably used as a weapon.
   a. Minor scalp injury consistent with victim's claim of head injury. (MR2)
   b. Broken bottle glass in and around tub. (CS2)
2. No major injuries sustained here.
   a. Complete lack of spatter or blood in this area. (BP1, CS2)
3. Victim in the tub/shower at the time of the assault.
   a. Liquid stains present near the entrance to the door. Possible sources are water or alcohol. Officers on scene do not record smelling alcohol, thus water is the most likely source. (CS3)
   b. Victim claims she was showering and was wet. (VS1)

Using this portion of the report, the reader understands that Event A was a disturbance in the bathroom. This event included three distinct event segments:

- The event began with the victim in the shower.
- A bottle was broken during the event.
- None of the bleeding injuries occurred in the bathroom.

To establish the occurrence of this event, the analyst called upon specific information within four other documents. This included page 2 of the medical report, page 1 of the bloodstain analyst's report, pages 2 and 3 of the crime scene report, and page 1 of the victim's statement.

The cross-references are particularly important, because they allow the reader to refer to all of the analyst's supporting facts. Oftentimes small but critical pieces of information, which tie together other pieces of information, get lost in the mass of documents collected during the investigation. A single item of this nature, which the analyst is aware of but the reader is not, can make a distinct difference in the conclusions drawn by both.

Here we present the remainder of the sample reconstruction report:

B: Altercation moves to main room. Bleeding injury sustained, but not a major one.

1. Victim ends up outside bathroom; no indication of standing on her own.
   a. Victim claims being pulled out of the room and falling to the floor. (VS2)
   b. Large stain on the floor, liquid intermixed with blood. No spatter or droplets present in the pattern. (CS2, BP3)
   c. Stain shows no foot marks, other than toe/finger drag marks. (BP3)

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2. Some bleeding occurs.
   a. No spatter or droplets present. Probable source very minor drips or venous flow. (CS3, BP3)
   b. Possible source of blood, minor injuries to the feet from glass cuts and/or the minor head injury. If the head, the head was near the ground.
3. Victim pulled from this location by force from the rear.
   a. Edge of the large stain near the bathroom door is undisturbed. (BP3)
   b. Stain boundary shows evidence of spines, indicating force of some nature was applied to the center. (BP3)
   c. Drag marks present in stain are consistent with dragging of feet or hands. Marks show motion in the direction of the bed. (BP3)

C: Primary assault occurs on bed.

1. Victim was on bed with head in the vicinity of the headboard.
   a. Saturation stains in victim's blood type. (SR2)
   b. All major bleeding injuries on victim's face. (MR2)
   c. Impact spatter show a point of convergence in this area. (BP2)
2. Impacts occur here; minimum of three blows.
   a. Impact spatter on two walls set injuries here. (BP4)
   b. Spatter establishes a minimum of three blows, but overall distribution is indicative of more. (BP4)
   c. Wounds on victim's face indicate at least three blows. (MR2)
3. Probable weapon is either the leg support or center supports of broken chair.
   a. Three sets of pattern transfers show characteristic measurements that are consistent with the leg support. (BP5)
   b. These stains indicate such an object was bloodied, rebloodied, and each time placed in contact with the bedding, near the victim's head. (BP5)
   c. Wounds present on the victim's face indicate a weapon with a linear edge, consistent with the support. (MR3)
   d. Size of impact spatter indicates a clear application of force. This spatter is inconsistent with mere hand strikes. (BP5)

D: Subject departs via window.

1. Window open with items on the ledge disturbed here. (CS6)
2. Pattern transfer present on outer window ledge in blood.

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a. Pattern has dual linear boundaries that are consistent with one measurement of the cross and leg supports. (BP5)
b. Pattern transfers indicate the object that made them came in contact twice at this location. (BP5)

Using the five source reports, the analyst defines to some degree four specific events and their supporting event segments and sequence. In this instance, the victim, brutally attacked and nearly killed, is unable to provide much detail regarding the actual assault. The reconstruction "fills in" sections where the victim's memory lapses and corroborates the remainder of her story.

Statement Comparison to Event Analysis

A second approach in crime scene reconstruction is to consider a subject or victim's statement as the reconstruction. In this method we take a statement presented as the "facts" surrounding some circumstance and apply event analysis to it. We then attempt to determine if the described events are supportable and whether they match the given sequence.

Accepting a subject's statement as the "reconstruction" is not that wild a thought. Those experienced at interrogation know that suspects don't always weave intricate and completely concocted statements when asked for information. As Avinoam Sapir reminds us, even when trying to hide the truth suspects often will provide very specific and factual information.[1] In terms of event analysis, when they talk to us they simply interject or leave out events and event segments or change the overall event segment sequence. Thus it is not the entire content of what they tell us that concerns us most; rather, it is the disjointed segments within the story we wish to identify.

Viewing the statement as a whole, these disjointed segments may not be evident. When viewing the statement against the context of event analysis, however, it becomes easier to determine if the statement is possible given the evidence available. The first step is for the analyst to create a complete picture of how the witness claims the event transpired. This may be difficult. The witness may have given several statements that must be combined to form the "reconstruction." Once this first step is complete the analyst, using event analysis, takes the evidence and applies it to each event and event segment. Contradictory events and disjointed segments will normally become self-evident in this process. If discrepancies exist between the analysis and the statement, this will provide the interrogator areas on which to concentrate subsequent questioning.

In effect, the statement becomes a hypothesis to examine given all available evidence. But the analyst must compile the hypothesis into a viable

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format that includes all claims and statements. Only when we understand all that is being claimed can we then decide to accept or reject it.

Event Analysis in Narrative Format

Both of the methods discussed thus far are quite functional for the reconstruction report, but neither conclusively leads the reader through the entire logic process. Some of the analyst's decisions may or may not be self-evident in these formats. The following is an example of the third approach — the narrative event analysis. It provides a clearer indication as to the specific reasoning used by the analyst. This narrative example is just a small part of the total reconstruction report concerning a double murder. For this reconstruction the reference key is as follows:

BP — Bloodstain pattern analysis report
CS — Crime scene report
FE — Firearms examiner's report
ME — Medical examiner's report
FM — Family members
RA — Reconstruction analyst's report
SR — Serology report
PR — Police arrest report

Event Segment Issues

Event Segment #1 — How did the subject gain entry to the residence? There are four possible options:

A. The subject used a key.
B. The door was left unlocked.
C. One of the victims let the subject in.
D. The subject forced entry.

Related information:

A key to the lock was found in the suspect's vehicle.	PR
Victim #1 was terrified of the subject.	FM
Victim #1 was known to always keep the doors locked.	FM
The child (Victim #2) was too young to open the door.	ME
The attack started at the bathroom.	CS, RA
No evidence exists of a forced entry anywhere in the home.	CS

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Evidence/information relationships: The attack suggests surprise as Victim #1 was preparing for the day. There are no defensive wounds and no evidence of struggle. If entry were forced, some evidence of that process would likely exist. Victim #2 was too young to reach or work the door lock and knob. Victim #1 had reported she was terrified of the suspect and, although not impossible, it is unlikely she would knowingly open the door and allow him in. A key was found in the suspect's vehicle.

Most probable occurrence: The lack of forced entry, Victim #1's prior behavior, and her known level of concern with regard to the subject make it unlikely events B, C, and D occurred. The presence of the key on the suspect and his knowledge of the residence layout make it likely he entered unnoticed using the key, catching the victim off guard as she was preparing for the day.

Event Segment #2 — Initial contact: Were the victims awake or sleeping at the time of the attack?
Two options exist in this instance. The victims were either awake or asleep.

Related information:

The bed appeared slept in and was unmade.	CS
The normal schedule for sleep had passed.	FM
The curling iron was plugged in and hot.	CS
Victim #1 had her menstrual period and a fresh, unstained panty shield was in her underwear.	CS, ME
There is specific evidence that both victims were present in the hallway at the beginning of the attack.	CS
Victim 1 had fresh makeup on her face.	

Evidence/information relationships: There is little to suggest that the victims were sleeping at the time of the attack. The condition of both the victims and the home make it almost a foregone conclusion that they were awake at the time the attack began.

Most probable occurrence: The victims were awake when the attack began.

Event Segment #3 — Mode of attack: In what order were the three modes of attack used on Victim 1?
There are three methods of wounding evident:

A. Gunshot
B. Knife wounds
C. Blunt trauma to the face

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Because we have three events with some sequence, there are several possibilities for that sequence. Using standard probability equations, these three options present six different possible orders, as evident in the following matrix:

Order #	1	2	3	4	5	6
	A	A	B	B	C	C
	B	C	A	C	B	A
	C	B	C	A	A	B

Related information:
Relating to A:

There is evidence of one gunshot to Victim #1 after she was dragged to the bedroom.	BP, SR
There is no visible blood trail in the hallway leading there.	BP, CS
Once victim is shot, there is no need to strike the victim.	RA

Relating to B:

There is evidence of cuts to Victim #1 in the bedroom.	BP, SR
The stabs and cut are peri-mortem.	ME

Relating to C:

The blunt trauma was the least damaging injury, causing a minor lip bruise.	ME
This blow would not render the victim unconscious.	ME
The victim's glasses were on the floor in the hallway.	CS

Evidence/information relationships: The least injurious blows are usually the first struck in the altercation. There is no indication of Victim #1's blood in the hallway outside the bathroom, but there is evidence of her blood from both cutting and gunshot events in the bedroom. Because all knife wounds are peri-mortem they most likely occurred last. Based on information evident in Event Segment #4, it is likely that Victim #1 was unconscious when moved to the bedroom, thus there would be no resistance.

Most probable occurrence: The most likely order for this sequence of event segments is #6 (CAB), with a strike to the face coming first, followed by at least one gunshot, and then the knife wounds.

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Event Segment #4 — Mode of death: What is the order of the fatal wounds to Victim #1?
There are three different fatal wounds:

A. Gunshot to the left ear
B. Stab to the heart
C. Gunshot to cervical vertebrae-2 (CV-2)

Once again, three possible events produce six different possible orders, as indicated by the following matrix:

Order #	1	2	3	4	5	6
	A	A	B	B	C	C
	B	C	A	C	B	A
	C	B	C	A	A	B

Related information:
Relating to A:

The shot to the left ear would have lowered the victim's blood pressure.	ME
Such a wound would not cause paralysis.	ME
There is time to use a pillow to muffle the noise for this gunshot.	RA
If first, the blood flow on the face should be different from what was found.	BP
This is a distant shot, left to right.	ME

Relating to B:

There are no arterial spurts present.	BP
This is a peri-mortem wound.	ME

Relating to C:

This wound would not lower the victim's blood pressure.	ME
This wound would cause paralysis.	ME
There is time to use the pillow to make this shot.	RA
This wound would cause little external bleeding.	ME
The wound is soft contact, left to right and back to front.	ME

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Evidence/information relationships: Event B, as the only peri-mortem wound, must occur last. This limits the orders to two (i.e., #2 and #6). Evidence indicates Victim #1 was dragged by the left wrist and forearm without indication of resistance. There are bruises present to support this. These bruises could form after paralysis, but would not occur after a drop in blood pressure. The blood flow supports Event A having occurred after the drag from the hallway. Thus Event C must have occurred before Event A.

Most probable occurrence: Sequence #6 is the most probable: gunshot to CV-2 followed by gunshot to the left ear, followed by the stab to the heart.

Note that for each segment the analyst defines the evidence considered, explains how that evidence relates to other evidence and information, and provides at least a glimpse into the reasoning process used to derive the conclusion.

The narrative report, although more difficult to prepare than the previous formats, doesn't require further action on the part of the analyst. All of the efforts detailed in the report are an integral part of basic event analysis. Whether using an outline or narrative format the analyst must still accomplish each step. When using the narrative format, the analyst simply describes everything in a little more detail. For each event segment in the narrative report, the analyst:

- Establishes the issue or question being considered
- Establishes the various possibilities
- Considers sequence as necessary
- Describes the information relevant to each possibility
- Describes evident pertinent relationships that impact on the conclusion
- Describes the most probable occurrence

The analyst may wish to use some type of supporting worksheet to help document the effort. Figure 10.1 is an event segment analysis worksheet. The worksheet has five parts. The *Investigative Question* identifies what problem is being resolved. Remember to be specific and deal with manageable issues. The *Event/Segment Issue* presents the viable options or hypotheses that might answer the question. The *Data On Specific Events/Segments* documents the information collected during the analysis that the analyst believes assists in answering the question. As much as possible this information should remain objective. The *Information Relationships* section is where the analyst explains how the pieces fit together. The analyst considers each possible hypothesis

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Event Segment Analysis Worksheet

Worksheet # ___
Investigation Question: _____

Event Segment Issue

Identify the specific event segment in question or identify the varying options involved in the event issue

A- _____

B- _____

C- _____

Data on Specific Event Segments

Identify the various facts that will assist in solving this issue. Include a cross-reference to where this information is found in the investigative files. ***Include only facts and not inferences***

_____

_____

_____

_____

_____

Information Relationships

Identify the specific relationships present in the evidence and information that allow some decision to be made. If sequencing event segments, identify why a given sequence can be eliminated, then mark it off the sequencing options box. ***Inferences may be included in this section.***

A- _____

B- _____

C- _____

1)	2)	3)	4)	5)	6)
A	A	B	B	C	C
B	C	A	C	B	A
C	B	C	A	A	B

Opinions as to the Most Probable Conclusion:

State your opinions based upon the analysis of the above data

_____

Figure 10.1 The event segment analysis worksheet is used to deal with a specific investigative issue.

in this section. The final section is *Opinions as to the Most Probable Conclusion*. Here the analyst answers the investigative question after giving full weight and consideration to the information examined. Figure 10.2 is a completed event segment analysis worksheet.

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Event Segment Analysis Worksheet

Worksheet # ___
Investigation Question: ***How Did Victim Leave The Bedroom?***

Event Segment Issue

Identify the specific event/segment in question or identify the varying options involved in the event issue.

A- ***Victim Left under Her Own Power***

B- ***Someone Carried Her out of the Bedroom***

Data on Specific Event Segments

Identify the various facts that will assist in solving this issue. Include a cross-reference to where this information is found in the investigative files. ***Include only facts and not inferences***

1. ***Blood Pool on Carpet (Crime Scene, Photographs; Actual Carpet)***
2. ***Very Little Movement Seen in Blood Pool (Photographs of Blood Pool)***
3. ***No Blood Drip Trail Leading out of the Apartment (Photographs of Floor)***
4. ***Garment Bag Missing from Closet (Police Reports)***
5. ***Blood Transfers in Step-father's State Vehicle Rear Seat (Police Reports, Serology Reports)***
6. ***No Bloody Palm or Fingermarks on Light Switches, Sink, or Door Handles (Police Reports; Lab Reports)***
7. ***Blood on Shampoo Bottle in Parents' Bath Consistent with Victim (Police Reports; Lab Reports)***
8. ***No Personal Clothing or Other Items of Victim Missing (Victim's Mom)***
9. ***A Packed Suitcase Ready for Church Camp Left at Residence (Victim's Mom)***
10. ***No Family Contacted from Time of Disappearance (Victim's Mom)***
11. ***New Garment Bag Purchased after Stepfather Questioned about Original Bag Location (Police Reports; Sales Clerk; New Garment Bag)***

Information Relationships

Identify the specific relationships present in the evidence and information that allow some decision to be made. If sequencing event segments, identify why a given sequence can be eliminated, then mark it off the sequencing options box. ***Inferences may be included in this section.***

A- ***When a person is bleeding enough to leave a blood pool on carpet there is usually evidence of where the person moved to after leaving the blood pool. It is quite common to find a drip blood trail, blood transfers on light switches, door handles, and sink handles when the victim gets up and moves around. A person who runs away from home usually takes personal belongings. Nothing was taken. There was a packed suitcase ready for travel and it was not taken. Victim has not made contact with any family members.***

B- ***If the victim is alive conscious movement is usually seen in and around the blood pool. The blood pool on the carpet shows little to no movement; there are no blood drips or blood trail leading from the blood pool. A garment bag is missing from the apartment. The blood transfers to Ben Crider's state vehicle, rear seat, are consistent with some bloody object being placed against the seat while the blood was still wet and transferring blood to the seat. There has been no contact with the family from the time when the blood pool was found on the carpet. No personal belongings taken.***

1)	2)
A	B
B	A

Opinions as to the Most Probable Conclusion:

State your opinions based upon the analysis of the above data

The physical evidence is consistent with someone removing the victim and inconsistent with her leaving under her own power.

Figure 10.2 A completed event segment analysis worksheet used to define why the analyst concluded that the victim was removed from a scene; in other words, that she did not leave under her own power.

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Matrix Worksheet

Case#: _____
Investigative Question: _____
Possible Options:

A. _____

B. _____

#	Evidence/Information Item	Option A	Option B

Key: C Consistent
I Inconsistent
N/A Neither supports nor refutes

Conclusion: _____

Figure 10.3 A matrix worksheet is somewhat simpler to use than the event segment analysis worksheet. Each piece of data associated with the issue is assigned a status of "consistent," "inconsistent," or "not applicable" (N/A).

Figure 10.3 is a matrix worksheet. It has four parts. The Investigative Question and Possible Options are filled out in the same fashion as the event segment analysis worksheet header was completed. The matrix section is completed by placing the data or information considered in the second column and then annotating the third and fourth columns as C (consistent),

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Matrix Worksheet

Case#: ***Day Two Practical***
Investigative Question: ***What position was the victim in when he received his major bloodstain-producing blows?***
Possible Options:

A. ***Suspect — Claims victim was on top of him kneeling over him and attacking. Suspect struck victim from below with right hand.***

B. ***Police Theory — Victim was seated on buttocks with suspect standing over him delivering the blows.***

#	Evidence/Information Item	Option A	Option B
1	Caked dirt on shoe heel. (H)	I	C
2	Apparent shoe marks in dirt.	C	C
3	Undisturbed blood flow.	C	C
4	Undisturbed spatter and leaves.	I	C
5	Victim in prone position.	I	C
6	Spatter on victim's back. (A)	C	C
7	Dirt embedded in ring. (E)	N/A	C
8	Spatter on the victim's sleeve. (B)	C	C
9	Spatter on the victim's chest. (C)	I	C
10	Dirt contact, left buttocks. (D)	N/A	C
11	Shoe mark with disturbed blood drops.	I	C
12	Arm abrasion. (F)	C	C
13	Punctate abrasion, right hand.	C	C
14	Dirt on left knee. (G)	C	N/A

Key: C Consistent
I Inconsistent
N/A Neither supports nor refutes

Conclusion: ***The evidence does not support the suspect's positioning claim, but is consistent with the police theory.***

Figure 10.4 A completed matrix worksheet dealing with whether a subject's claim about his position is possible or not. Unlike the event segment analysis worksheet, the matrix does not show how the analyst interrelates the information.

I (inconsistent), or N/A (not applicable). The final section, Conclusion, outlines the analyst's conclusion for the problem. Figure 10.4 is an example of a completed matrix worksheet.

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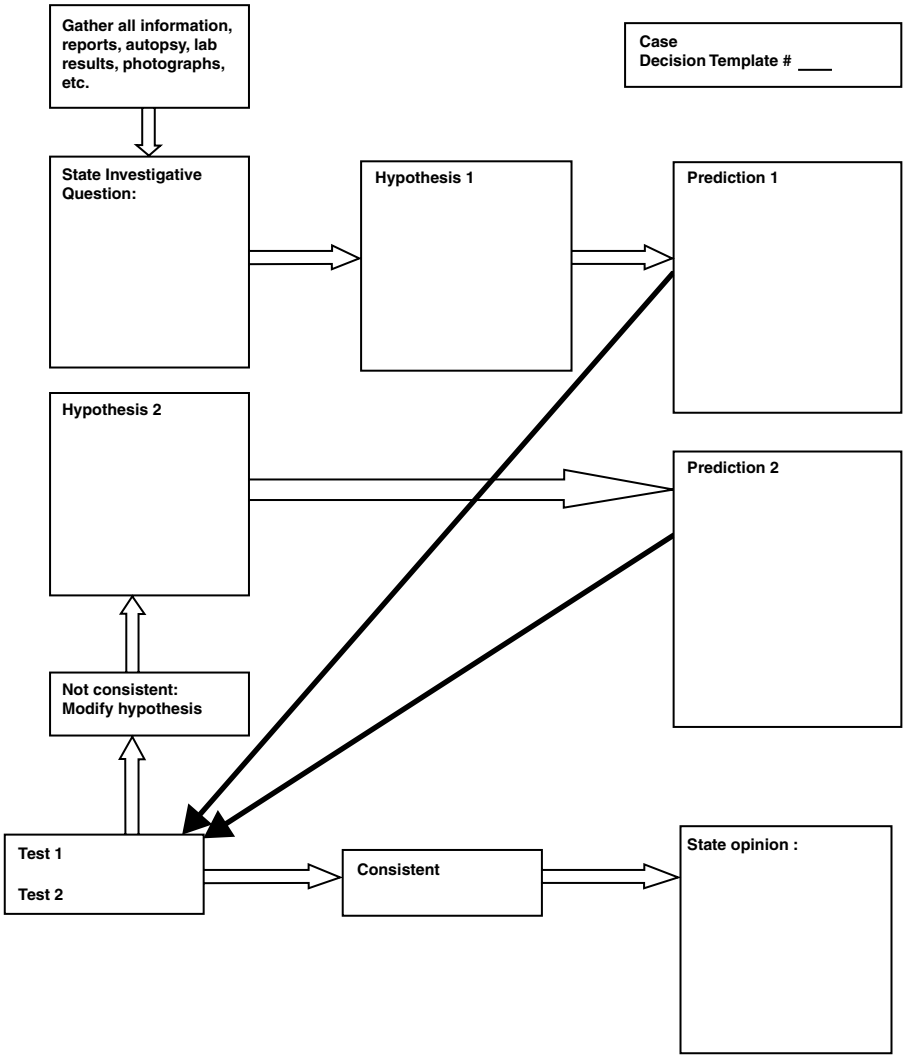

Figure 10.5 The scientific method template simply reminds analysts of the various steps they must go through to seek their answer.

Figure 10.5 is a scientific method template form. It follows the basic scientific method for formulating the question and developing the hypothesis. Figure 10.6 is a completed form.

Whatever method analysts use to detail a reconstruction, it must allow them to follow their logic and decision process. All of the relevant information that supports the decision should be evident, and the report should have a clear cross-reference that allows any reader to refer to specific investigative documents supporting a given decision.

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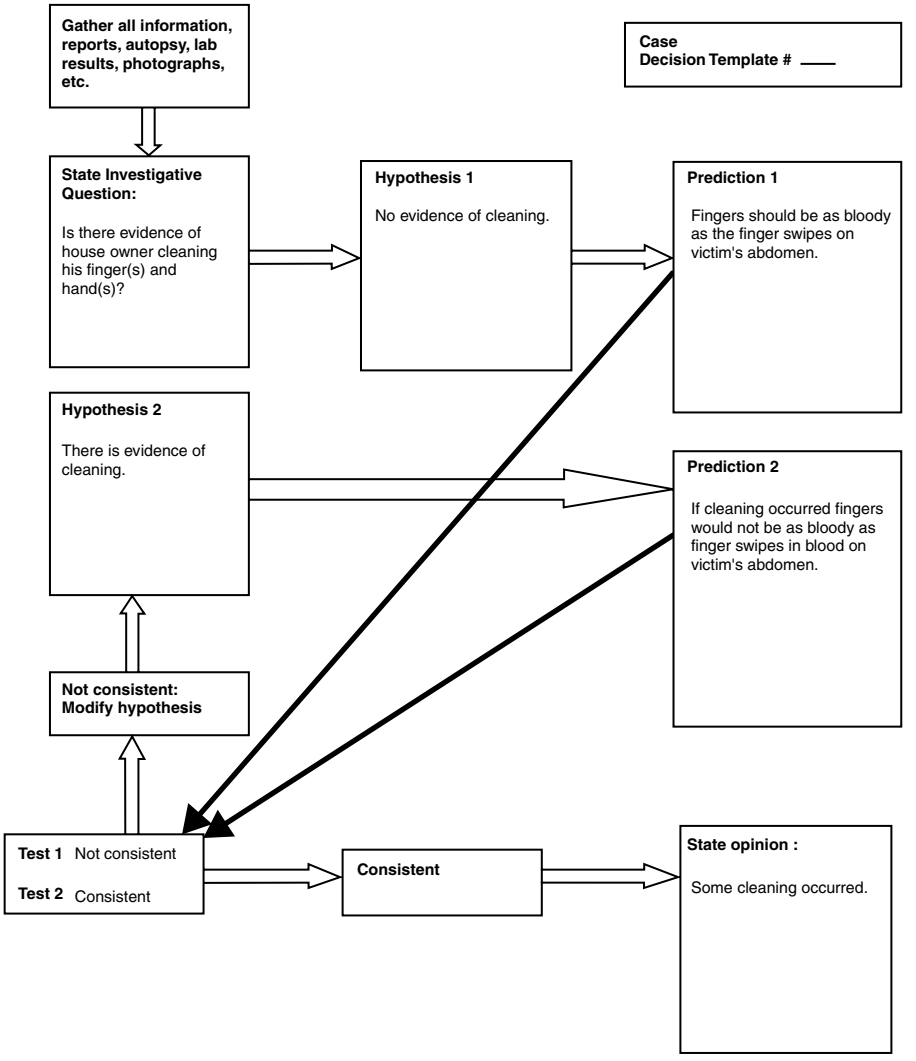

Figure 10.6 A completed scientific method template dealing with the issue of whether some cleaning occurred at the scene of a shooting.

Remember, the reconstruction product or conclusion is not infallible. What the reconstruction report offers the analyst is a greater level of self-scrutiny. Links between evidence become clearer and analysts can often discover weaknesses in their own decision making. In particular, analysts are far more likely to recognize situations in which they use contradictory arguments. Such a product also makes it easier for analysts to revisit their reasoning processes in preparation for court. No small detail of the original analysis is forgotten; nothing is left out. The reconstruction report also provides a format

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for trial, presenting the investigative conclusion in a logical and structured form that is easily followed and understood by the jury.

Guidelines for Maintaining Objectivity during Case-Specific Experiments

In unraveling the investigative puzzle, the analyst must often conduct some manner of experimentation to clarify a given event or event segment. This is particularly true for the bloodstain pattern analyst, who must often decide if a specific event can create a given stain.

The goal of any such experiment, whether developed for bloodstain pattern analysis or crime scene reconstruction, is simply to include or exclude some event or set of events as a source of the questioned pattern or result. With this in mind, let's consider some guidelines and pitfalls that affect the reconstruction. The following factors and guidelines will assist the analyst in maintaining investigative focus. These guidelines may also prevent the reconstruction from becoming too subjective.

Define what is at issue. What exactly are you trying to establish or learn? Be clear from the start and maintain your focus throughout the effort.

Consider all possible explanations for the result or pattern. Analysts shouldn't go looking for "their" answer. They should at least consider all possibilities, even if they appear improbable.

Eliminate the ridiculous. Particularly when considering bloodstains, given a little time and a little ingenuity, the analyst can reproduce a particular pattern in any number of ways. For example, 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 don't waste investigative resources and time on flights of fancy.

Brainstorm with others. Don't rely soley on yourself to maintain objectivity. Ask investigators, analysts, attorneys, or individuals not directly involved for input.

Concentrate on "elimination." Concentrate your efforts on eliminating from your possible list those things which are "not consistent." Don't put too much emphasis on "identifying" an event. It is not always the case that the analyst can associate a set of circumstances to a specific event and absolutely exclude all other possibilities. Simply eliminating impossible circumstances, however, can bring a level of clarity to the situation.

Using these guidelines, analysts are unlikely to find themselves lost in the maze of possible event sequences without a specific investigative focus. Just the same, they are also more likely to maintain their overall objectivity and not follow a singular investigative theory. No matter how experienced the investigator may be, this is a delicate balance to maintain.

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Re-creating Human Anatomy

In many instances of bloodstain pattern analysis, the need arises to re-create an event that involved a specific part of the anatomy. In considering attempts to re-create the structure of human anatomy for such evaluations, the first question of concern is: Is it necessary? To the analyst trying to re-create some specific event, this is certainly a critical question. The question, however, assumes that human anatomical structures *can* be re-created. We doubt this is really possible nor do we think it is necessary.

Even if analysts could replicate anatomical structures (e.g., general bone and tissue structure), what they cannot replicate is the dynamics of the underlying circulatory system. In most instances this is the most relevant issue, because analysts are concerned with the dynamics of the force and its effect on the blood (e.g., whether a given force can produce a specific size of spatter). They are less concerned with the effect of the force on the anatomical structure (e.g., whether the force can cause the same damage to the bones and skin). The true volume of blood present due to the injury and the pressure behind the flow of that blood are factors that no one can reproduce, yet these factors obviously affect the ultimate pattern observed by the analyst.

Given the combined knowledge of the discipline developed from live subject experiments, cases where the manner of wounding was known, and the experiences of "wounding" sponges, we have found that bloodstain patterns are reproducible. Thus, analogies from bloodstain pattern experiments seem to be more than adequate, making the accurate replication of human anatomy unnecessary.

Re-creating Event Particulars

Just because we don't think it necessary to re-create human anatomical structures doesn't mean the analyst should ignore other particulars of the event.

First, we need to return to our consideration of what is at issue. Wherever the analyst has an investigative question, it must be considered with an appropriate focus. For instance, a pattern transfer re-creation is usually concerned with the manner of application of the object, whereas a spatter re-creation is more likely to consider the nature of the force. In order to maintain the focus, analysts must re-create the event particulars to the best of their ability.

Wherever possible, match the particulars of the event to the re-creation. If the re-creation involves blows, the analyst must consider the range of force. If a pattern transfer is in question, the analyst must either use the instrument in question or find one that matches it closely (e.g., same model

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or construction). Certainly surface characteristics need to be matched; for example, matching a particular tile, fabric, or material on which a pattern is found. Orientation may also be of significance, so don't assume the way you use the object or bring two items together is the only way to do it.

Pitfalls to Re-creation/Reconstruction Attempts

There are many pitfalls in re-creation/reconstruction attempts. The following are some of the more common ones 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 re-creations we often employ a group effort and thus group think is common. Any concerns or criticism by team members of the methods employed should be objectively considered.

Designing an experiment to prove your result. Because 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 example, 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 obviously will not cause spatter.

Failing to take a holistic viewpoint. Tunnel vision in the individual or the group can eliminate objectivity and doom re-creations to failure. Design the experiment around the case facts. Consider the results with those same facts in mind. If analysts know they're 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.

Arbitrary exclusion of events. If you choose to exclude some event or segment as being possible, then know exactly why you feel the exclusion is warranted. "Gut feelings" and "because I think so" are not adequate reasons for absolute exclusion in a reconstruction.

Case Examples

The following are two case examples that may allow the reader to gain a greater appreciation of how to apply these guidelines and avoid the pitfalls.

Case Experimentation Example #1

Facts of the case. 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 (Figure 10.7).

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Figure 10.7 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.

Issue in question. The primary question in this case is how the bloodstain on the wall (Figures 10.8 and 10.9) could have been created from this shooting occurrence. The stain was 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 evident upward and slightly to the left. There was a large number of micromillimeter stains surrounding the main bloodstain. There was also a bullet ricochet to the right edge of the main area of the bloodstain. The blood was tested and found to be consistent with the victim.

Brainstorming by peer input. Photos, a scene diagram, and a synopsis of the facts were sent to two peers. Two different opinions were returned for consideration. One peer felt that an exit wound was missed at autopsy. To investigate 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 theory, the bullet extracted at autopsy was weighed and compared to the weight of a whole .38 round. The resulting information excluded this possibility.

Brainstorming by the investigative group. The firearms examiner, bloodstain analyst, serologist, detective, and crime scene technicians participated in a round-table discussion to consider possible occurrences. One thought offered was a volume of blood entered the barrel of the weapon resting on the bed. The gun was then held up toward the wall and fired a second time by another party.

Initial test design. This possibility was tested using the same weapon and ammunition. About half an eyedropper of blood was placed into the barrel

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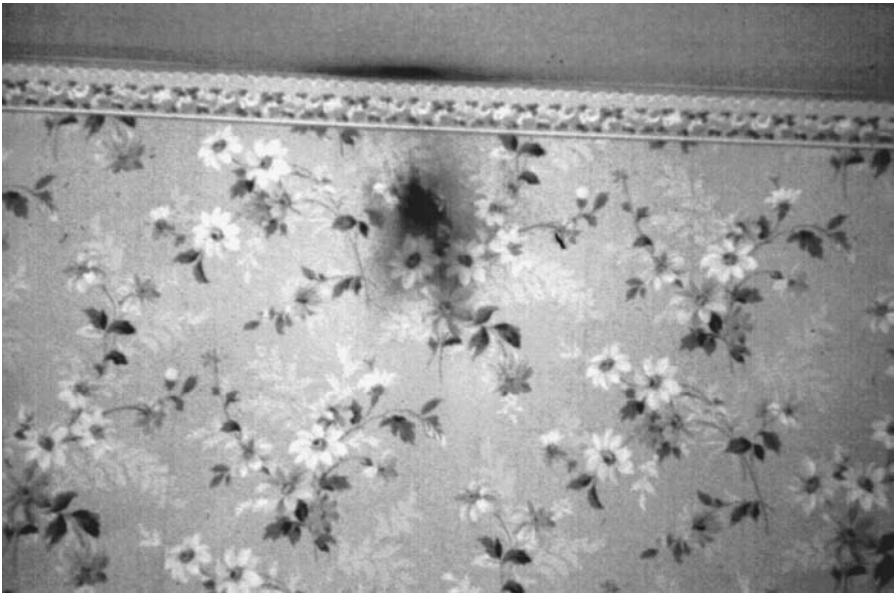

Figure 10.8 The pattern shown here was present on a nearby wall, but more than 6 ft away from the victim. The blood present in the stain was determined to be consistent with the victim. Given the final position of the victim, the lack of an exit wound, and the atomized nature of the stains in the pattern, the pattern could not be reconciled with the known facts.

and the weapon 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.

Second brainstorming. At a subsequent discussion, one of the participants mentioned that all of the variables had not been considered. The participant suggested 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.

Redesign of the test. 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 stain pattern was replicated, complete with a bullet hole to the edge of the main pattern area (Figure 10.10).

Conclusions. 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, which 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.

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Figure 10.9 A close-up photograph of the stain in question. The stain reflects distinct features typical of a high-velocity impact spatter, 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. The reader may note in Figure 10.8 a distinct ricochet pattern present on the ceiling above this pattern. This clearly indicates a volume of blood was involved in the creation of this pattern.

Case Experimentation Example #2

Circumstances. A passenger in a fleeing vehicle shot a .30-.30 rifle at the pursuing police officer, striking the officer's vehicle three times. At the end of the chase the vehicles collided and came to rest 33 ft apart on opposite sides of a roadway. The officer, unable to free himself from the seat belt, observed the driver of the vehicle standing in front of the open driver's door. The suspect was attempting to recover a rifle from the driver's side floor area. While seated, the officer drew his service weapon and fired five shots out the window. The suspect was hit twice in the upper and mid-back.

Issue in question. The defendant's family filed suit against the officer and his agency for wrongful death. The suit alleged that if the suspect had been located as claimed by the officer, the two bullets exiting him would have struck the vehicle. No such strikes were evident, nor were the bullets found.

Peer input. An investigative team reviewed the photographs, a scene diagram, autopsy report, accident investigation, and a synopsis of the facts. One consideration was that the bullets, on exiting, might have gone through the open window of the driver's door. A second issue for consideration was the actual condition of the area between the front edge of the driver's door and the vehicle. To understand the relationships, the investigative group decided to try a reenactment.

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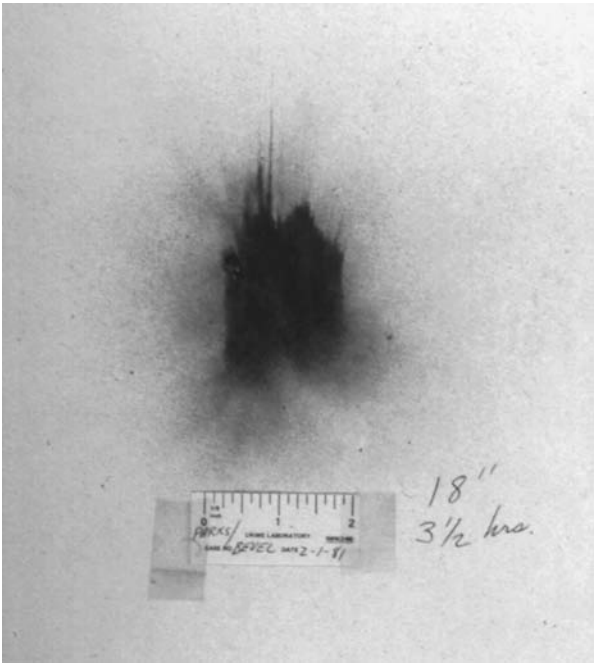

Figure 10.10 A photograph of the stain created during a re-creation. By allowing the blood to congeal in the revolver for 3.5 h, the subsequent pattern produced was quite consistent with the pattern found at the scene (Figure 10.9).

Test design. The scene was re-created using an individual similar to the subject and similar vehicles. A laser site was chosen to recreate the weapon. Bright-colored patches were placed on the simulated suspect at the point of entry of both wounds. This allowed the investigative team to see and document the laser. All parties and objects were placed at the scene as they were alleged to have been placed at the scene of the incident.

Reenactment. Using all information available, the vehicles were placed in the same positions as on the night of the shooting incident. The officer was positioned in the driver's seat of the police vehicle. He drew his weapon with the laser site and aligned it with the patches on the simulated suspect.

Conclusions. In considering the officer's position and possible positions for the subject, the following was evident that:

> If the suspect was in front of the open driver's door as claimed, it was still possible for bullets exiting his person to miss the vehicle. This was due to the angle and difference in elevation of the vehicles combined with the height of the suspect. The bullets exiting would actually travel above the top edge of the driver's door.

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The idea that the bullets would take this latter path was not considered in the original group discussions. As is often the case, only through a reenactment did the total dynamics of the situation and scene become apparent.

Summary

Ultimately, the final form of any investigation is a reconstruction of some nature. To be useful to the court, the reconstruction must be clear, concise, and to the point. The reconstruction report is a written account of the logic process the analyst utilized to reach the conclusions and should lead the reader through each point of the analysis.

Incorporating our concept of event analysis from Chapter 2, the reconstruction should include each supportable event and event segment. The analyst should include details regarding specific items of evidence that support these event segments, then briefly explain their interrelationships.

Because the reconstruction report is a compilation of many different sources of information, the analyst should also cross-reference this information. The cross-reference serves an important function in keeping sight of all supporting evidence. Small, minute details scattered throughout the investigative report often allow some specific conclusion to be reached. Without a cross-reference, these small details are often lost or forgotten in the total package.

In seeking a conclusion, analysts often have to re-create events or conduct some form of experimentation. In these instances, analysts must know what they are trying to establish. Pragmatic objectivity is the key to success. Don't arbitrarily rule out any possibility; but then again, don't try to prove the foolish. When designing experiments and re-creation attempts keep the focus clear, seek the advice of others, and maintain an open mind.

By following the guidelines and format explained in this chapter, the analyst's reconstruction report will ultimately serve any fact-finder in determining the most probable sequence of events for a given incident.

Reference

1. Sapir, Avinoam, *Scientific Interrogation Course Manual,* LSI Inc., Phoenix, AZ, 1991, p. 31.

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Automation Applications in Bloodstain Pattern Analysis and Crime Scene Reconstruction

11

We live in a digital age and computers abound throughout our society. As we become cognizant of computer capabilities we tend to automate more and more processes. This is certainly true in forensics. In Chapter 6 we discussed programs that allow us to define the point of origin for a given set of bloodstains. This type of software is just one example of how automation resources are enabling the analyst to better conduct analysis. In this chapter we will consider some of the ways in which automation supports crime scene analysis, bloodstain pattern analysis, and overall crime scene reconstruction.

Automation Usage Considerations

Although some may see the application of computer resources in analysis as inappropriate or unnecessary, that is far too limited a viewpoint.[1] The accuracy and capability of computers far outweigh our own abilities in some instances. Computer analysis is nothing new to the reconstruction business. Using state-of-the-art graphics packages, engineers have for years conducted accident reconstruction. Early on, the limitations of such usage were simply access to a "mini" or "mainframe" computer resource and the money to fund the expertise for such an endeavor. Today, access to a computer is the least of the analyst's problems. The mini-computer, once thought to be "high end," now pales in comparison to the capabilities of the PC available to the average high school student. Walk in to any computer warehouse and you can buy a computer capable of running at speeds of 900 MHz, at an affordable price. Access to software is no longer restricted. Similar, if not the same, software packages

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that once ran on mini-computers are available through any computer software vendor. Given time, nearly anyone can learn to use these programs.

Despite the availability and widespread acceptance of computer resources, those who voice concerns about automation advances are not completely wrong. There are acceptable uses and even limitations in their application. Unfortunately, little effort has been put forth to explore and thus define the future of the computer in the field of reconstruction and bloodstain pattern analysis. Although we recognize that automation serves a very functional purpose in both areas, there are still many issues that need resolution. Are all three-dimensional (3D) presentations scientifically valid? Are they too prejudicial? Will a jury, in "seeing" rather than "hearing" an expert's opinion, place more credibility in that opinion than it deserves?

We don't claim to have answers to these questions, but just as we see the potential of using automation in reconstruction, we also recognize a need to consider the downside of its use. To some, the answer has been "let the court decide." If forced to, the court will certainly set limits for the analyst, but forcing the court to act is probably not in the discipline's best interest. That attitude removes the responsibility of the discipline's experts to consider and set appropriate standards. If the experts fail to set standards one can be certain that lawyers will.

Types of Applications

The breakout for generic groupings of software applications varies from author to author. Reese saw automation applications as one of simulation, tutorial function, and illustration.[2] Alexander described four groupings for applications: Category 1 — basic mathematical solutions that are tedious (e.g., velocity determinations) but easily verified by human examination; Category 2 — graphics for illustration of opinion; Category 3 — simulations based on standard equations; and Category 4 — experimental simulations not easily verified by human examination.[3] Gardner presented the groupings in a similar fashion, making three distinctions in software: teaching tools, computer-aided analysis, and illustrative tools.[4]

For the purposes of our discussion, we will use three groupings: tutorial, simulation and computer-aided analysis, and illustration.

Tutorial Applications

Tutorial applications allow the analyst to instruct someone on a given concept or theory relevant to the discipline. Although Reese saw this solely in the court setting, tutorial software is also available to assist students learning about bloodstain pattern analysis.

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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. Several figures produced from *TRACKS*® models were shown in Chapters 4 and 7. Although primarily intended for students, *TRACKS*® may eventually find its way into the courtroom to clarify teaching points to the jury.

Few other tutorial applications are currently 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 the artificial intelligence 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 with the system asking specific questions and the student giving answers.

Simulation and Computer-Aided Analysis Applications

Simulation or computer-aided analysis is an area ripe for development in the reconstruction field. Simulation applications allow the analyst to take basic data from an event and then, using known equations, create a simulation of some part of the event. Computer-aided analysis software takes data from the scene and allows it to be manipulated and viewed in a different manner. Both the simulation and analysis method allow the analyst to test beliefs regarding an event, determine if the data available match the circumstances, and in general allow for a more in-depth analysis.

Accident reconstruction has used these types of program for years in an effort to refine and enhance the efforts of the accident investigator. Over the past few years, accident investigators have watched the development of what are now commonly referred to as "total stations," laser measuring devices with receivers that allow nearly effortless and accurate collection of crash-site data. In some instances these programs have migrated to crime scene documentation, but that trend is still in its infancy. Companies such as Sokkia have created hand-held computer devices that allow for this data collection. Once completed, the data is then downloaded to proprietary software that manipulates and converts the scene data into a DFX format. The investigator pulls up the DFX data in any CADD program and can manipulate it further. Simulation software also exists which takes such data and allows the investigator to accurately establish yaws, vaults, and similar events associated with crash investigations.

For bloodstain pattern analysis the software *Backtrack Images*®, as discussed in Chapter 6, is useful. It takes basic data collected from the scene

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and, using standard formulas, determines the impact angle and gamma angle for a given stain and then graphs that information in various fashions to allow the user a better understanding of the data.

Also discussed in Chapter 6 were *Backtrack®, Backtrack/Win®*, and the program previously available as *No More Strings©*, simulation software packages that allow the user to evaluate spatter patterns. The software, using standard equations, does the tedious math necessary to define the point of origin. It then presents the data in both text and graphics. Each uses standard equations and physical laws to determine where a droplet may have originated. The programs provide a fairly accurate estimate or representation of the spatter event.

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 so that they are more useful.

Image processing software, although relatively new to bloodstain pattern analysis, is not new to forensics. Document examiners and other forensic scientists have used these software systems for some time.[5] Some of the image manipulation and enhancement routines available to the analyst in off-the-shelf software packages include pattern elimination, color modification, edge determination, and adjustments to contrast, brightness, or intensity.

In pattern elimination the analyst identifies a color belonging to some unwanted pattern and then removes it. As a result, unwanted patterns are diminished in the image. This allows the analyst to better view adjacent patterns or see the pattern as a whole.

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 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 Color Figures 17 and 18,* which demonstrate this technique in enhancing a spatter and transfer pattern. In the original photograph (Color Figure 17) the dried bloodstains appear dark and do not stand out well against the blue color of the pants. Reversed (Color Figure 18), the pants become red and the patterns become white, making their form and boundaries much more evident.]

* Color Figure 17 and 18 follow page 134.

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Edge determination is a method in which the computer analyzes the image, looking for specific edges in the patterns. Once again, the identified edges are enhanced, allowing better visualization. Because the system identifies these edges mathematically, it may locate patterns not immediately evident to the human eye.

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 image value, whereas 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, and 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.

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 (Figure 11.1). 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 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 (Figure 11.2). 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 11.3 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

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Figure 11.1 This crime scene photograph shows 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. Note also the lack of a scale of reference. (Photograph courtesy of Henry Muse, Dallas, TX.)

appropriate for every single case, but in instances where a significant enhancement might make the difference, they are available.

Illustration Applications

The use of automation for illustration has grown significantly in recent years. Illustrations can range from simple graphics to a detailed animation. Their function is always the same: such methods help illustrate the expert's opinion to the court. For that reason they are generally held to be demonstrative evidence, which is important for reasons we'll discuss later.

From the graphics perspective, analysts have used illustrations to show wound characteristics, bloodstain pattern characteristics, crime scene layouts, and other similar information. The most typical approach is to digitize a photograph, which the analyst then enhances by adding "highlights, labels, croppings, overlays, or scaled comparisons."[8] A specific benefit of graphics is that a wound characteristic can be shown without the accompanying gore, which the court often finds prejudicial. Graphics allow for both the isolation and demonstration of a specific characteristic and the elimination of the offending images.

Another illustration application is the three-dimensional sketch program, which is gaining popularity over traditional crime scene sketching methods. Since 1989, access to crime scene sketch applications that run on the PC and Mac platforms has been commonplace. These applications allow

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Figure 11.2 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.)

the analyst to re-create the scene in two-dimensional and three-dimensional perspectives. Many also incorporate a low-end virtual reality or animation approach. After creating the scene the analyst can choose a position from which to view the scene or combine a series of views. In this fashion the analyst or jury can make a virtual walk-through of the scene.

Most of these crime scene programs allow the analyst to create two views: either a line drawing rendition or fill-in drawing. The first is typical of the graphics seen in a standard CADD view, where objects are depicted as transparent, like those in Figure 11.4. The fill-in view presents the scene and information with a more realistic perspective, as in Figure 11.5. Just about any home design software available today provides the analyst with effective demonstrative aid tools.

More complex animation and design programs allow the introduction of people into the scene. Not only can analysts recreate the scene, but they

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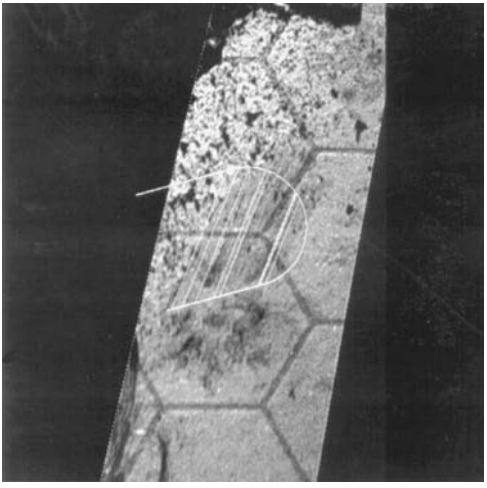

Figure 11.3 E-Systems of Dallas was able to enhance the original photograph (Figure 11.1) to this end product. Using a mathematical model, the analyst filled in the missing detail from the pattern transfer and highlighted the entire enhanced pattern in white. Although certainly an "alteration" of the original image, this is an example of a substantive-type programming technique that may well serve analysis and reconstruction in the future. (Photograph courtesy of Henry Muse, Dallas, TX.)

can also introduce scaled victims and subjects, placing them in any position desired. Analysts often use these applications to illustrate the position/location of the individual at the moment of wounding. This is particularly effective for demonstrating an expert's opinion on possible and impossible positions.[9,10]

Animation, although clearly linked to our discussion of three-dimensional scene viewing, is an application in and of itself. Forensic animation developed out of the efforts of accident reconstruction, particularly in the area of vehicular collisions.[11]

In animation not only are the scene and players re-created, but the players (e.g., victim and subject) are repetitively positioned within the scene. Different views are created, showing event segments, then the entire series is shown in sequence. It is important to recognize that this process is distinctly different from showing people or objects in static positions within the scene.

The intent of forensic animation is to show the analyst's view of how the events proceeded. Once again, used in this fashion the animation is demonstrative only. As Reese points out, "[the animation] does not determine 'what happened'. The accuracy and credibility of a forensic animation is a product of the skill of the animator and the accuracy of the expert or lay witness who will authenticate the animation."[12] If the basis of the crime scene analysis and reconstruction are tainted, then the animation serves little purpose.

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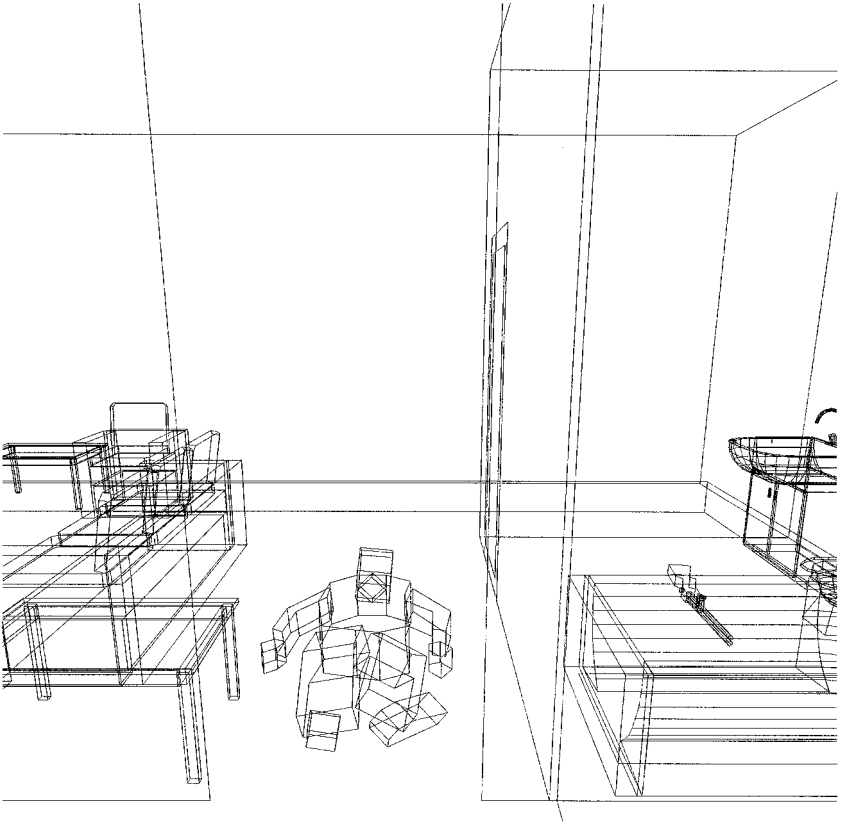

Figure 11.4 An example of a three-dimensional view of a crime scene. This example is in a line drawing rendition, in which all objects are transparent.

Views regarding the use of forensic animation in the criminal justice system vary. We personally feel full-fledged animation is too subjective. If you recall our discussions of event analysis, the analyst is probably lucky if a majority of the specific events that make up a given incident can be defined. Obviously, full animation requires the analyst to fill in the unknown event segments, and it often assumes that no other actions occurred. Unfortunately, the analyst has no real assurance that this is true. It may simply be a situation where evidence indicating the occurrence of the other actions is obscured.

In considering this concern, look at Figure 11.6. Imagine a situation where we have three distinct time windows, all based on specific physical evidence at the scene. All of these established event segments occur in a small area within a hallway and appear to be sequential. With no other evidence to suggest any other action on the part of participants, the animator would likely sequence them one after the other with little or no time

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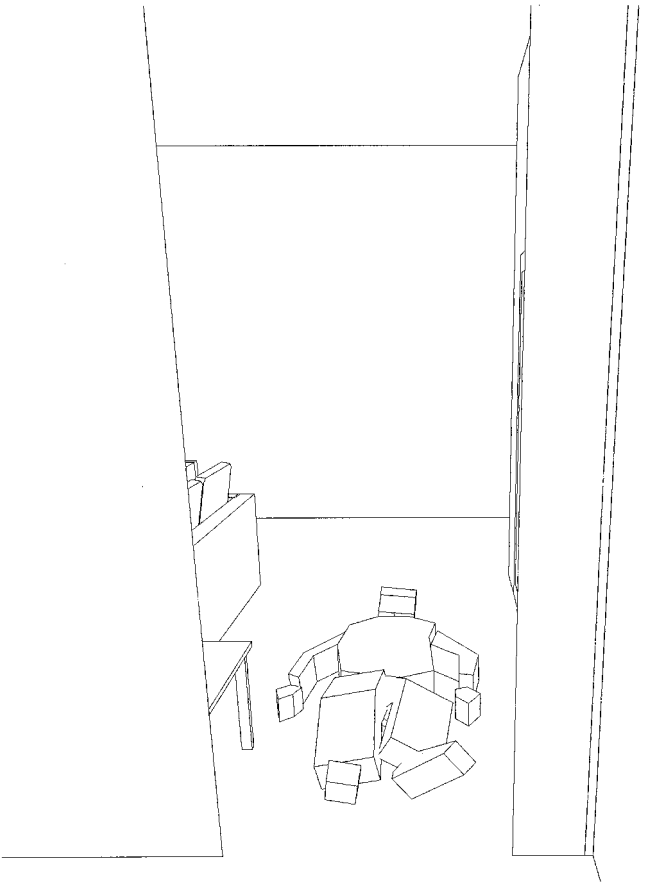

Figure 11.5 An example of a "painted" view of the same scene. The computer hides all lines not normally evident to the viewer, creating a more realistic view of the scene. Many sketch programs allow the analyst to create a number of views and then show them in sequence. In effect, this creates a virtual walk-through of the scene for others to see.

in-between. Unfortunately, there is nothing that precludes Optional Windows A or B, or both, from having occurred between Time Windows 2 and 3, nor is it likely the analyst would ever find evidence to support these actions. Either action, however, could drastically alter the court's beliefs with regard to the entire incident.

Animation often demands major assumptions, and these assumptions impose a level of subjectivity into the reconstruction. Granted, it can be argued that even if we present the reconstruction using the storyboard method (one graphic for each event segment, shown sequentially, but not animated), we still would not be aware of these other actions. Whether we

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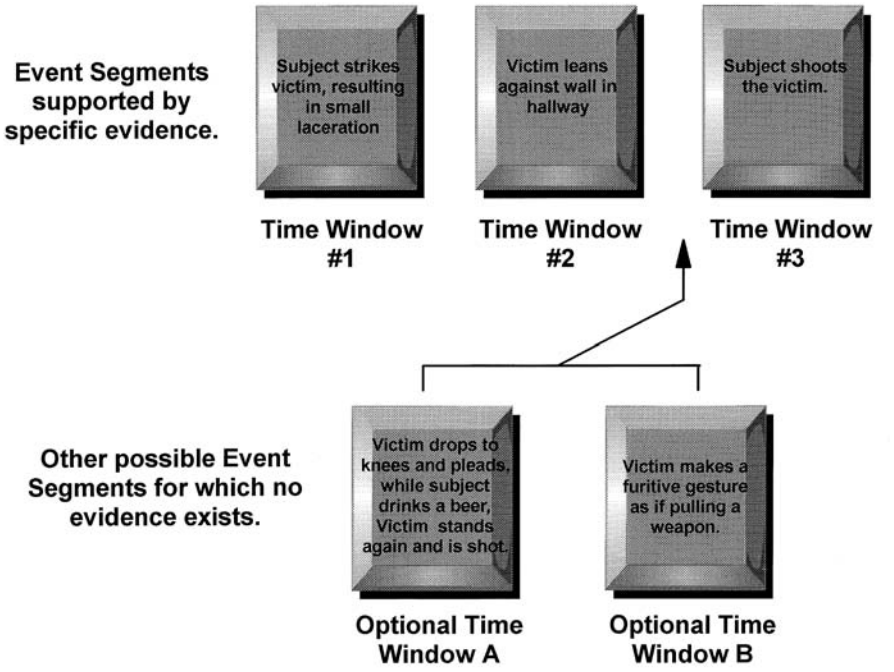

Figure 11.6 When considering event analysis and animation, the analyst must be cognizant of the limitations in using animation. We rarely know enough to claim that we can recreate the entire incident. For instance, the evidence may clearly establish that Time Windows 1 through 3 occurred in sequence. But we may never know what other actions occurred in between. Between the moment the victim leans against the wall in this example and the point when the subject shoots, either of the optional time windows (A or B) could have happened. Full animation often demands that we make an assumption that nothing else occurred in the course of the event.

would or could discover their occurrence is not the point; the objective is presentation of the reconstruction. In the animation method the analyst is forced to introduce obvious subjectivity concerns, whereas in the storyboard method the reconstruction remains accurate to what the evidence actually establishes.

In some instances, full-fledged animation is both possible and perhaps viable in presenting event reconstruction. For instance, in a case in San Francisco, Alex Jason combined the timing of a series of shots recorded in a 911 call along with physical evidence from the scene. Taken as a whole, this allowed a somewhat solid basis to present an animation of the actions of the victim during his murder.[13] In this particular instance the establishment of a very clear timeline, with little intervening time between each shot, allowed this. Nevertheless, the analyst can never be sure whether some other action was

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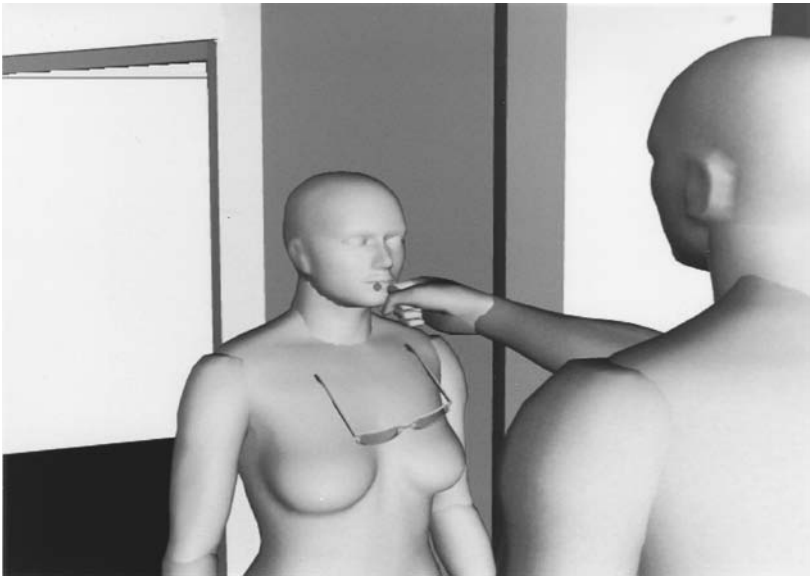

Figure 11.7 This computer-generated snapshot depicts a single event segment relating to a multiple murder. This segment depicts a blow to the face of the victim. This is Event Segment #3 from the narrative format reconstruction report example in Chapter 10.

taken in between these established events. This concern will remain the most aggressive argument against full-fledged animation in forensic reconstruction.

An alternative to full-fledged animation is to demonstrate event analysis using animation software. Established event segments are created and shown in a series, which become true "snapshots" of the crime. Figures 11.7 through 11.10, created by Ken McCracken of Video Solutions in Norman, Oklahoma, demonstrate this process.[14] Each snapshot is then presented, one at a time, as the analyst explains his or her theory. These images are shown in the appropriate sequence, using either a still video or hard copy. In a way, we are physically creating Rynearson and Chisum's concept of a "story board."[15] This approach to animation usage is perhaps best, because it eliminates subjective fill-in by the analyst. It also precludes many of the arguments against animation, while still allowing the court to "see" the reconstruction.

Another benefit of this technique is the ability to adjust to successful objections by opposing counsel. If the judge rules that a specific image or event segment is inappropriate, the analyst need only remove that particular image from the overall reconstruction. With an animated reconstruction, this is much more difficult. A full-fledged animation can rarely be edited in a timely manner and certainly not on site.

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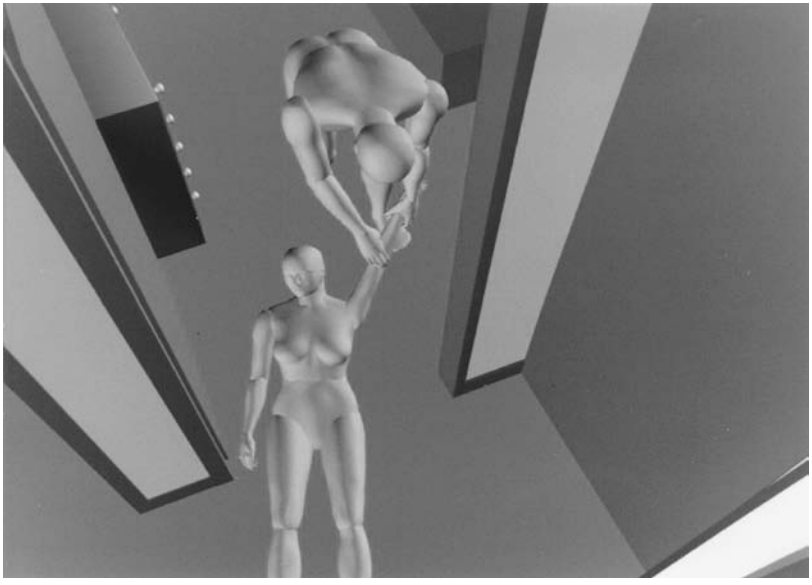

Figure 11.8 This segment depicts the subject dragging the victim to another room. Once again, it is a specific snapshot of the crime established by specific facts and knowledge. This segment is Event Segment #3 from the narrative format reconstruction report example in Chapter 10.

Court Acceptance

A critical concern in using automation is the fashion in which it is presented. If demonstrative (i.e., the evidence is used to illustrate and demonstrate a given expert's opinion), the evidence will face fewer challenges in the courtroom. On the other hand, if the evidence is substantive it is likely to be judged in a more critical light.

There are few true substantive applications available at the moment. Alexander's description of Category 3 and Category 4 modeling applications are perhaps the best explanation for a true substantive program. He described such applications as situations in which "Known variables are given to the computer, and from these variables, a computer is able to construct an illustration based upon standard equations programmed into the computer."[16]

The concept of a substantive application is distinct from the demonstrative application. For instance, whereas *Backtrack*® might assist the analyst in defining the probable point of origin for a spatter-producing event, the analyst could then demonstrate this knowledge using a three-dimensional crime scene. *Backtrack*® helps the analyst establish the point of origin — it gives the analysis something new; therefore, it might be considered substantive. On the

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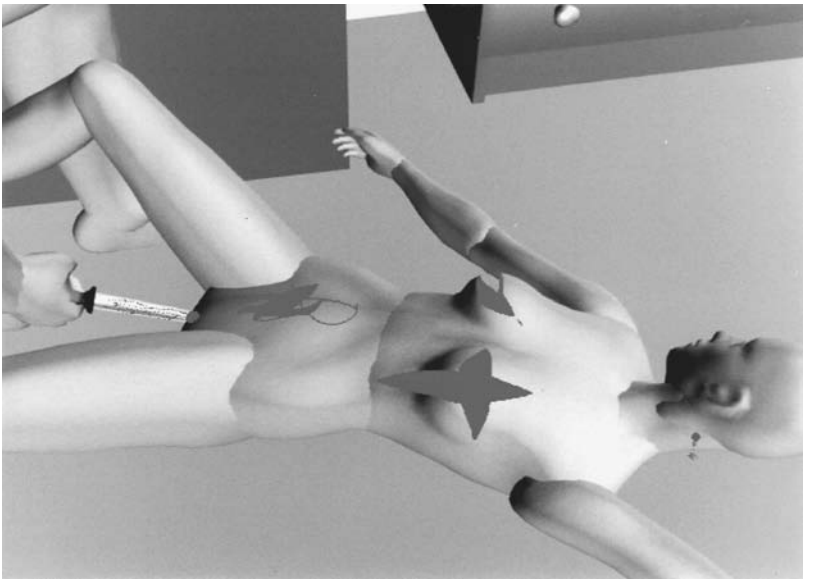

Figure 11.9 This segment depicts the sexual mutilation of the victim, following several other fatal wounds. Although certainly graphic, the computer-generated image is often more easily accepted than photographs. In fact, three jurors from the subsequent trial commented that they were better able to listen to the testimony when viewing these images. They found it difficult to follow verbal testimony when viewing the actual wound photographs, which were extremely graphic and disconcerting.

other hand, the crime scene sketch application doesn't "tell" the analyst anything with regard to the analysis; it merely helps to show his or her opinion based on the information derived from the substantive application.

Nonetheless, just because a demonstrative program is not held to the same rigorous test for admissibility as the substantive one doesn't mean that anything goes in the courtroom. The court has placed clear limits on the use of this technology. Any application or evidence presented must be relevant to the inquiry and be reliable. Two areas in which the court has taken specific issue with such evidence are the passage of time and the validity of the actions demonstrated.

Although a "walk-through" of the three-dimensional crime scene is generally accepted, the introduction of movement by parties in the scene is viewed more negatively. The experiences of Dr. Daniel Davis, a medical examiner in Minneapolis, demonstrate that the court can be picky in this regard, and rightfully so. In one instance when he used diagrammatic footprints in a scene to show the most likely path an assailant took, the court argued that Dr. Davis didn't really know how many steps the assailant took in moving along this path or that the assailant took the most direct

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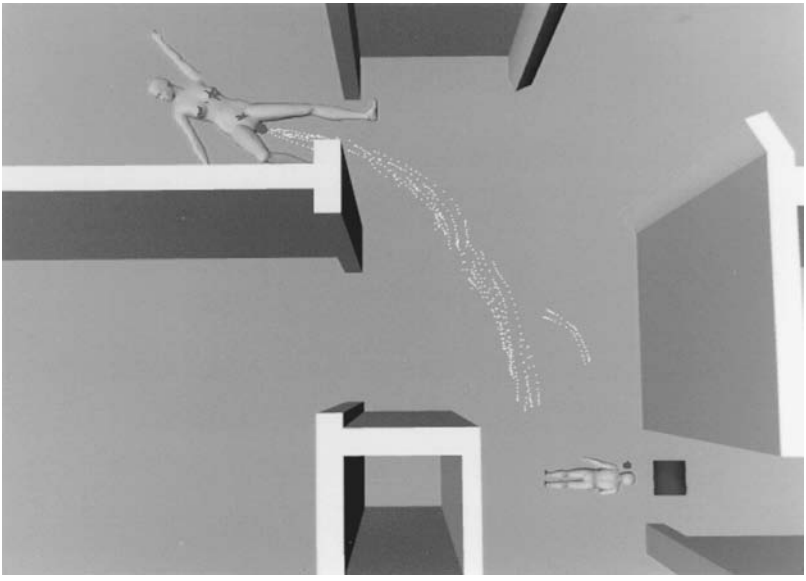

Figure 11.10 Computer imaging with virtual reality software allows the analyst to create a view of the scene from any position. In this image, the viewer is provided with a bird's-eye view of several rooms from the scene. It allows the viewer to orient the position of the two victims and the blood trail discovered using luminol.

route. Aside from this concern, the judge found the remaining demonstration acceptable and, after removal of the offending footprints, allowed its use.[17]

In another instance, Peter Barnett encountered a judge's objection while trying to use animated figures to demonstrate the position from which several shots were fired. The objection was based on the issue of time. The judge had no concern with the positioning demonstration, but argued there was no evidence to support the time depicted by the animation. In the end the animation was allowed, but only after the jury was clearly advised of the judge's concern.[18]

Building Demonstrative Presentations Using Computer Resources

The ability of jurors 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 such presentation will simply put the jury to sleep. Demonstrative presentations help the jury understand the interrelationships

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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, we 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*[19]or *Lotus Free Lance Graphics*.[20] This program is the heart of the presentation, and it helps to be fairly familiar with the basic working of the presentation software. All of the other programs will provide input to this package.

The second software package required is a CADD or a home design software program. Examples include *Punch Pro*[21] and *3D Home Architect*.[22] They create architectural-style floor plans and 3D 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 3D-rendered screens in a standard graphic file format (e.g., BMP, WMF, or JPG)

The third package required is a human figure design package, such as *Poser*.[23] These programs allow the user to pose virtual models in any position desired. Important features include:

- Ease of use. You won't work this program all the time, nor will you use it to its full extent. But when you need it you want to be able to use basic processes easily.
- The ability to use different model formats (e.g., life-like, stick-man, or mannequin).
- 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 into graphic files that can be imported into the presentation software.

A computer, the presentation software packages, and scanner are usually found in most police agencies. They represent the bulk of the cost associated with purchasing these items. Home design software is relatively inexpensive

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and ranges in price from $50.00 up to $100.00. Human animation programs cost as much as several hundred dollars.

Before we discuss 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 large. Don't try to jam 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 analyst may force the judge to 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 3D representation of the scene. Using the CADD or home design software, the analyst first creates a two-dimensional 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, then size them accordingly.

Once the floor plan and furniture are complete, the analyst can render 3D views from various perspectives. The analyst does this by aiming a virtual camera at specific points in the two-dimensional plan. The software then renders a 3D 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 depends on the location of items of evidence. The same rules apply to the virtual camera as to a normal camera. Whenever possible, keep the lens and primary subject aligned; don't 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

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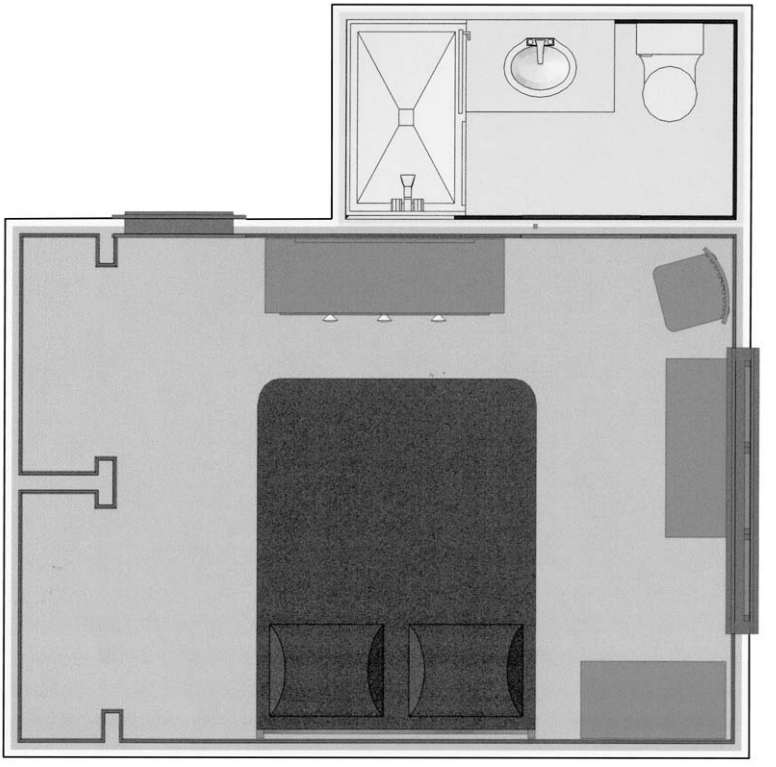

Figure 11.11 An overhead view helps orient the jury to the scene itself and items of furniture. Used in conjunction with the crime scene sketch, it provides a full understanding of where things are located.

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 obtaining 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 (Figure 11.11). Create other views from "within" the room as needed, then export them (Figure 11.12). Most export methods produce a BMP or WMF graphic file, either of which can be imported into the presentation software. [Note that 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 DFX or similar file. This is not the export needed for the presentation. Exporting a 3D room view creates a graphic image file. This function is found in the File menu only when the 3D-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, it will be more difficult to locate them when you need them.

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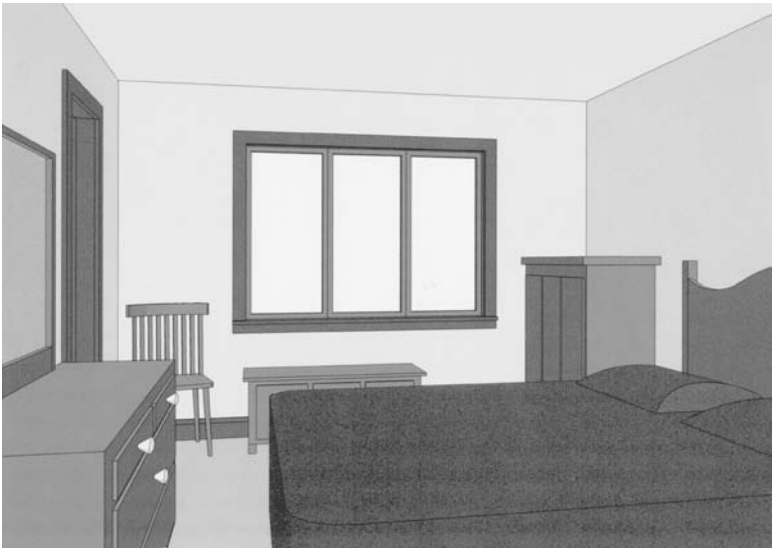

Figure 11.12 These programs allow the placement of a camera to create a view from anywhere within the scene. In this example we show the view across the room from the doorway. The software will usually accommodate whatever view is necessary. The view is then exported as an image (usually a bitmap) and imported into the presentation software.

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, then you'll need one presentation file with three blank slides to start off with.

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've 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.

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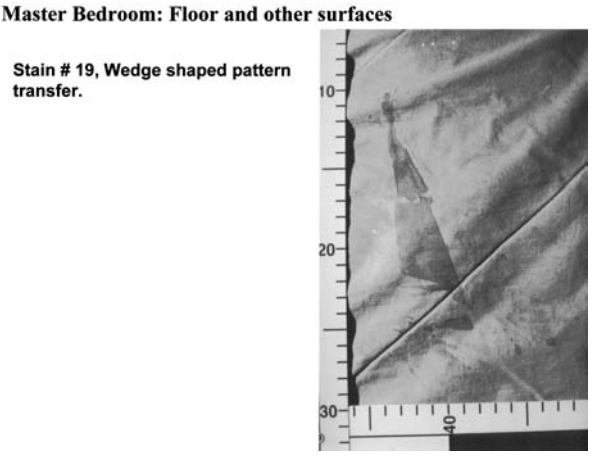

Figure 11.13 Part of a series of presentation slides shown in a murder trial. This slide shows a scene picture of a specific stain, providing specific information regarding its identity (Stain #19) and general location (master bedroom).

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; 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, simply ensure it is on screen or highlighted 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 you saved the room views.

Don't 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.

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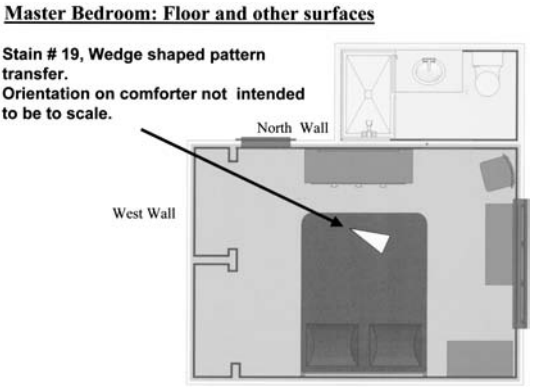

Figure 11.14 This slide combines the image of the overhead view created in CADD software with arrows and graphics to show the specific location of Stain #19 in the scene.

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, choose Insert from the dialog box. The screen will return to the slide edit mode, where you can size the picture as needed.

Human figure animation software is used to create figures in various poses. These are imported in a similar fashion to the presentation software. However, it is difficult to combine both a 3D room view and a figure. Depending on the method used to export each image, intermixing the two is nearly impossible. There is one alternative. Programs such as *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.

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. We prefer a presentation that alternates between a scene photograph and a room view. This combination will ensure that the jury members can see the particular stain being discussed and that they know its exact location in the room. Figures 11.13 through 11.18 are case examples of the resulting product.

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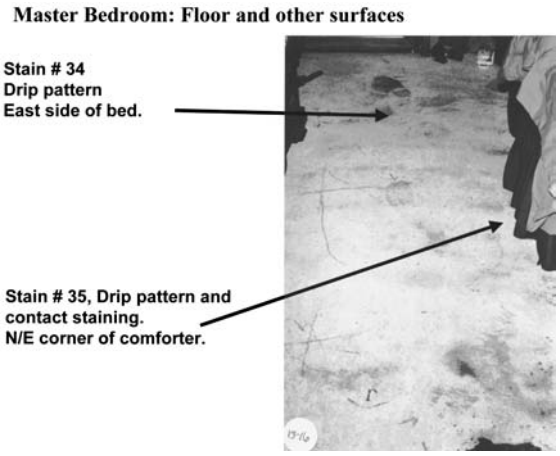

Figure 11.15 This slide shows two stains on the floor of the bedroom (Stains #34 and #35). The arrows allow the analyst to show exactly where on the photograph the jury should look to find the item. This is effective when multiple stains overlay one another in a given photograph.

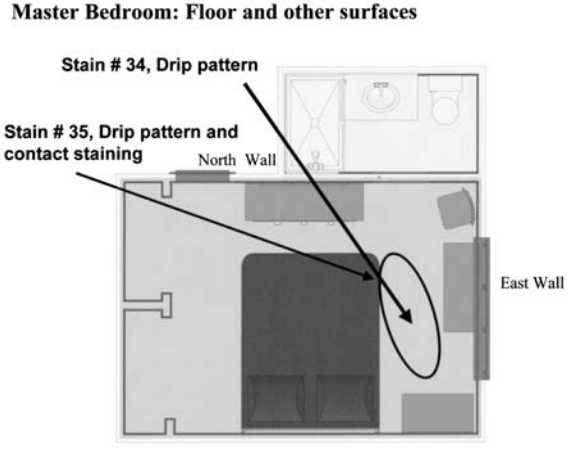

Figure 11.16 Another overhead view orients the position and extent of the two stains, helping the jury better understand what the analyst saw at the scene or on the evidence.

Summary

It should be evident to our discipline that there is a growing body of decisions that reflect the court's desires and limitations. Whether judged by a *Frye* or *Daubert* test, the court will apply some level of scrutiny to the use of automation. The best guidance for the moment is to apply automation objectively

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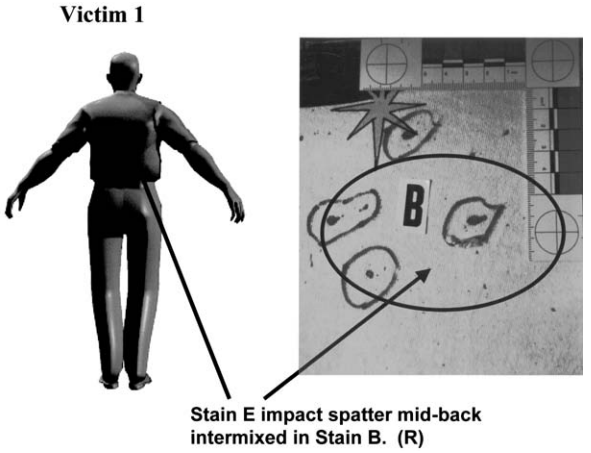

Figure 11.17 In this slide human animation software was used to create the "representation of the victim." Just as we used the scene views and photographs, this slide allows us to specifically orient the position of Stain E to its position on the body of the victim.

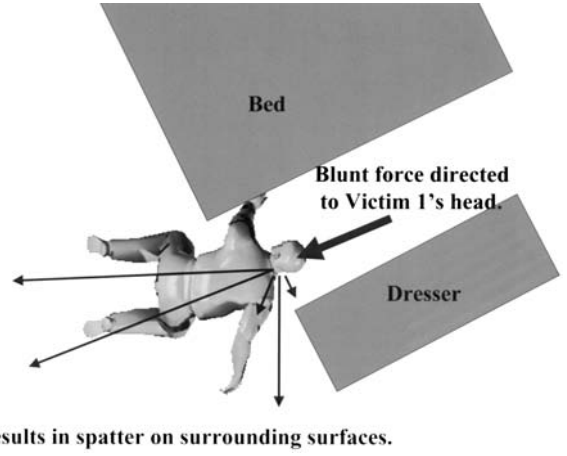

Figure 11.18 After placing the "model" in a position, we generate additional graphics to demonstrate the position and its relationship to the presence of several stains in the scene.

and cautiously to any analysis. Steer clear of subjective considerations and present only those facts that are easily supported. As Dr. Davis comments, "Just because it's possible to [demonstrate something] on a computer doesn't mean that it's realistic to push it on the court. It may be 'cool' but it may also be imprudent."[24]

Analysts are just beginning to recognize the full benefits of automation applications in analysis. The concern for the future should be defining accept-

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able methods of application. If the discipline fails to take a lead in this process, then we can be certain the court will impose limitations of its own without the benefit of the discipline's insight.

Whatever the outcome of this concern, the analyst should recognize that automation brings distinct benefit to the reconstruction effort because it allows the analyst to look at and present information in a completely different light. This is particularly true when creating demonstrative aids in court. To that end, the computer may well be one of the most valuable tools available to the analyst in the future.

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Presenting Evidence at Trial

12

Preparation for court begins long before any actual court date. Analysts who fail to prepare properly 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 and expectations of the court, then perhaps we deserve such treatment. The culmination of any analysis is to demonstrate in court the conclusion drawn from the analysis. In meeting that end the analyst can never take preparation for trial lightly.

General Concerns

Analysts should investigate and prepare reports in every case with an eye on the witness stand. Their own reports can often come back to haunt them, so they must not contain inaccuracies, discrepancies, exaggerations, and unsupported theories. When writing the report the analyst must keep this question in mind: How can I substantiate what I document in court?

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. It is neither uncommon nor inappropriate for an analyst to use stage blood or other inert substances to demonstrate bloodstain dynamics. This may include dripping blood onto angled targets or creating spatter. As discussed, computer resources are also helpful in this regard. They can effectively illustrate specific events and points related to the analyst's testimony.

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The ability of the analyst as an instructor is a concern that can't 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 the analyst's job to help an attorney win the case; 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 such behavior can destroy the analyst's overall credibility.

Nevertheless, pressures to be "one of the team" will exist. 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 vs. them" attitude found in the adversarial court system.

It takes a conscious effort by the analyst to remain impartial, but reconstruction and analysis demand this impartiality. This might seem at odds with our purpose, because certainly the analyst will eventually conclude that something happened and that someone was involved. Being adamant in the conclusion isn't a bad thing, but the analyst becomes adamant only by evaluating all evidence and considering all possibilities. The ultimate conclusion objectively recognizes inherent strengths and weaknesses. This kind of impartiality is a far cry from pursuing only evidence that supports a specific theory. Impartiality demands we recognize the difference between the two and pursue the holistic approach.

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 the most probable sequence of events has been established based on all evidence available. Of course, the court works in a slightly different fashion. As Peterson explained: "The principle objective 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]

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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 are the ones 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 a 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. Analysts own their integrity; no one can take it from them. To lose it, you have to make a conscious decision to give it away. Guard your integrity carefully, because every time you take the witness stand both the court and society are relying on it.

Settling In and Establishing a First Impression

Often, it is the first few moments on 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. Because analysts know their own qualifications better than anyone else, they can create questions that place them in a positive light. Of course it is imperative that analysts not embellish their 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 where analyst has taught the subject
- The number of times previously qualified as an expert witness
- Membership in professional organizations related to the field

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Preparing these questions in advance and providing them to the appropriate attorney ensures that: (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. Don't 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 at all 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 shouldn't be viewed as "timid." Analysts must appear confident in their knowledge, experience, and conclusions. If you act like a professional on the stand, the jury hopefully will perceive you as a professional.

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. 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 develop in a variety of ways, but quite often counselors simply set the stage and allow analysts to impeach themselves. Opposing attorneys are trained to bring out any attitude of animosity or bias, and they 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 or acquit, but rather to give whatever testimony that 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 only a short answer, such as "yes" and "no," look only at the attorney asking the questions. Don't look back and forth from the attorney to the jury during a series of such

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questions. The jury may find the motion disconcerting. On longer answers, the analyst should look to the jurors. In doing so, the analyst builds rapport and further establishes an image of credibility. 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, then become immediately defensive or hostile when the opposing attorney asks questions. No matter how aggressive an attorney becomes, the analyst should never get angry 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. What does count 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 any number of objectives, including:

- Discrediting the witness
- Discrediting the discipline or methods used
- Discrediting the ultimate conclusions or opinion 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 own reports. 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 conclusions they did.

Event analysis is the best method we know of for assisting the analyst in accomplishing this end. No matter how flustered or hurried the attorney makes you, the supporting information is always at your fingertips if you have prepared a thorough event analysis reconstruction report.

During cross-examination expect the opposing attorney to dwell on those areas in which you are not qualified. An example may be the attorney

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who asks if the analyst has a degree in physics, math, or biology. Often, the attorney will then attempt to make the analyst answer simple questions from one of those fields. 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 big complex questions that ultimately leave the analyst embarrassed. For example, in bloodstain pattern analysis, even though the analyst is not a serologist, the attorney will often ask a serology question. 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 don't belong in court.

An associated ploy is to hand the analyst a reproduction from some book, lab manual, or bloodstain experiment, and then ask if the analyst can determine 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 that might support or refute any opinions made? An analyst doesn't 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. However, if you are forced to answer a question about a specific book or article, you should always demand time to read 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 three general 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," whereas 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 …?"[4]

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

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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 or she would prefer to have answered first. The analyst must recognize the attack for what it is and respond. In this instance, attorneys don't want answers; they are trying to confuse the witness. A good counter to this technique is simply to pause after every question. Because analysts are charged with answering the attorney's questions, they also have some control over the pace. Should the attorney interrupt you while you are talking, you can simply stop and wait. Once the attorney stops talking, you can then ask the court to allow you to complete the answer if needed. Slow down the pace and don't become flustered by the attorney's actions.

In answering any question be cautious of offering "yes" or "no" responses, because the attorney will often go to great lengths to keep you from saying anything more. 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 testimony to the court. Commonly used aids include diagrams, charts, and photographs. Additional demonstrative aids include:

- Foam heads or bodies
- Dowel rod trajectory displays
- 3D computer graphic stills
- 3D computer-generated videos
- *PowerPoint* presentations
- In-court reenactments
- Video reenactments
- Foam board models

Inexpensive foam heads, available from beauty product stores, are used with dowel rods to demonstrate trajectories. The trajectory rods are placed accordingly to show entry and exits demonstrating the path of the projectile (Figure 12.1). A more expensive foam model is now available commercially. It comes in adult male, adult female, and child sizes. The body, arms, legs, and head all accept trajectory rods and have a full range of motion so the model can be placed in any position. It is imperative when using this type of aid to verify the alignment with the appropriate pathologist.

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Figure 12.1 A Styrofoam head with trajectory rods used to help illustrate specific wounds and how they relate to the scene.

To show shooter and victim position or orientation and the effect of interactions during a shooting, a trajectory rod display is very useful (Figures 12.2 and 12.3). This device can be built with Velcro, elastic, and stiff foam rubber to fit different parts of the body, such as the head, arms, chest, or legs. Once it is adjusted over the wound site, trajectory or dowel rods are placed into the foam rubber, demonstrating the flight path of the projectile(s). The use of a laser trajectory pointer with such a device is also effective. Both methods allow the person acting as the victim to move into different body positions, thereby demonstrating how the trajectory may change with body movement.

Recalling our discussion of event analysis, 3D-rendered computer graphic stills for each event or action to be testified to can be created as well. These assist the jury in understanding testimony. There are several advantages to their use:

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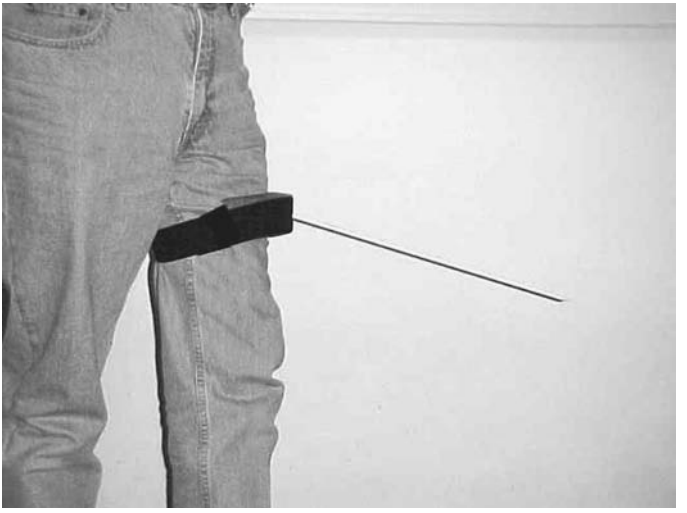

Figure 12.2 A Velcro and foam device in which the trajectory rod is placed and then attached to the body. This allows a more dynamic understanding of how the movement of an individual may affect the alignment of a given trajectory. In this photograph, with the leg straight, the trajectory is slightly downward.

Figure 12.3 In this photograph, the movement of the leg as in running, lifted the possible trajectory of the wound significantly. These devices can effectively demonstrate to the jury why a given trajectory is possible or impossible.

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- They are about 1/3 the cost of creating a moving computer graphic video.
- If the court rejects one or more of the pictures, they are easily removed. A moving video is much more time consuming to edit at the direction of the court.
- The 3D renderings direct the jury's attention away from the blood and gore of viewing photographs of the actual victims; thus the jury is more likely to hear the testimony.

Three-dimensional computer-generated videos are also effective, but are very expensive to produce. The videos allow the court and jury to "see" the analyst's theory of what happened in a 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 the expert's conclusion regarding what occurred.

PowerPoint and similar presentation software packages are excellent media with which to present photographs, sketches, and other computer-generated images. One caveat, however; never make changes after sending a presentation to the court. The process of changing material is so easy it is hard not to resist making these last-minute improvements. The presentation must be 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* help the analyst present 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.

Court reenactment is another effective tool. It can be done in court or it can be videotaped and then played in court for the jury. One important point: always know what the result of the reenactment will show prior to reenacting it. This is especially true for the in-court reenactment. Pre-court video preparation allows for more time to prepare a professional video that is true to the reenactment and clarifies all points the analyst wishes to make.

A tool not used as often, but still effective, is the foam board model of the scene (Figure 12.4). These models allow the jury to see spatial restrictions and relationships among furniture items and room locations as well as locations and interrelationships of evidence.

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,

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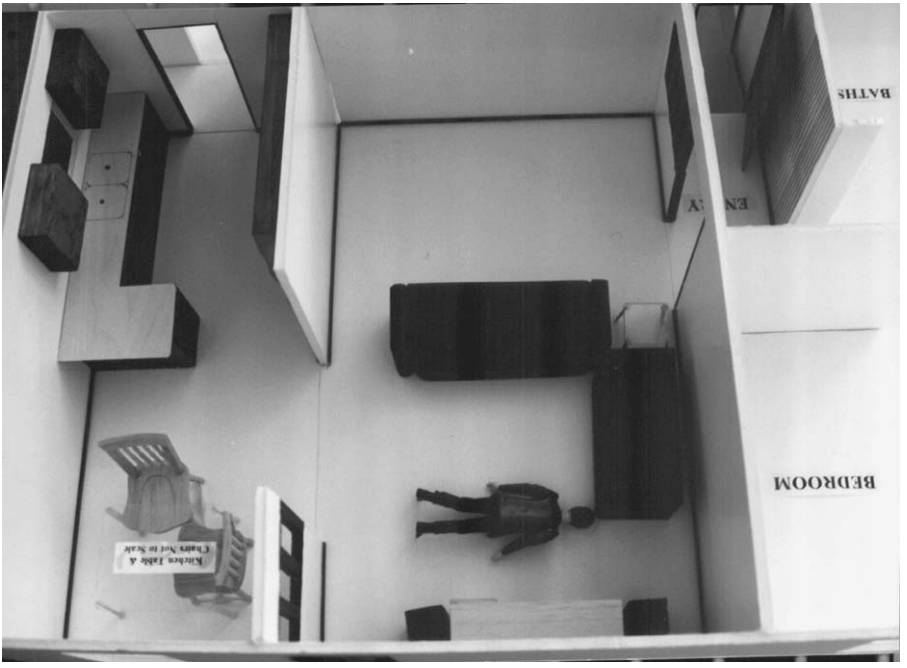

Figure 12.4 The foam core model. Although not used as often due to the availability of software programs, such models are still effective tools.

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 melodrama.

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 who must ultimately decide the issue will likely accept the testimony.

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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 controls to their employees. In an informal survey in 1993, Stewart found 43 out of the 70 departments he queried without any comprehensive policy in place. More than 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

Two specific diseases pose an immediate hazard to the analyst: HIV and hepatitis. The human immunodeficiency virus, or HIV, is the most talked-about threat to law enforcement officials who work in bloody scenes. For those exposed to the virus, it very often results in acquired immunodeficiency syndrome, or AIDS. The virus destroys the host's ability to fight off other microorganisms, which allows the development of 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

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transmission (other than through consumption of breast milk or sexual contact), the degree of the exposure required is not great. A simple needle stick injury is sufficient contact to cause infection. In fact, Stewart goes so far as to caution against contact with chapped skin or mucous membrane areas because these may also represent infection avenues.[3]

Of specific concern to the analyst is the virus' ability to survive. HIV 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.[4] Temperature has a direct effect on survivability: refrigeration delays the degradation of the virus whereas heat speeds up its demise.[5]

The second threat, hepatitis, is a virus that causes mild to severe liver damage in the infected host. It results in jaundice, cirrhosis, and in some cases, cancer of the liver.[6] In the more severe instances it can result in death. The virus is transmitted in much the same fashion as HIV, through contact with blood, semen, vaginal secretions, and saliva.

Crime Scene Considerations

As indicated, the survival of these pathogens at the scene is not uncommon. 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 who 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 additional considerations that demand 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 to accomplish that 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 on anyone with access to the crime scene, because they represent a source of exposure to viruses. Cuts, abrasions, or sores offer potential access routes for infection. Individuals with such injuries should approach the scene with extreme caution and, if practical, they should avoid the scene completely. Certainly as a minimum protective measure, the individual should wear double-layer protective clothing.

The analyst should show a distinct concern for preventing exposures that result from accidents. Crime scene processing and searches are filled with

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possible sources of injury and exposure. 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. The analyst should use double-layer techniques whenever possible. The purpose of the clothing is actually twofold: protection from accidental exposure at the scene and prevention of subsequent incidental contact with blood products tracked out of the scene. Disposable booties, outer garments, and gloves are the minimum requirements. Eye goggles and face masks should be used to reduce possible contact from splashes or airborne particles, particularly during operations in which this risk increases (e.g., during the collection of stains). See Figure 13.1.

Unfortunately, methodologies clash in this regard. The most appropriate method of collecting dried bloodstains for DNA analysis is by scraping and collecting the entire stain. This scraping increases the overall risk to the collector, because 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.

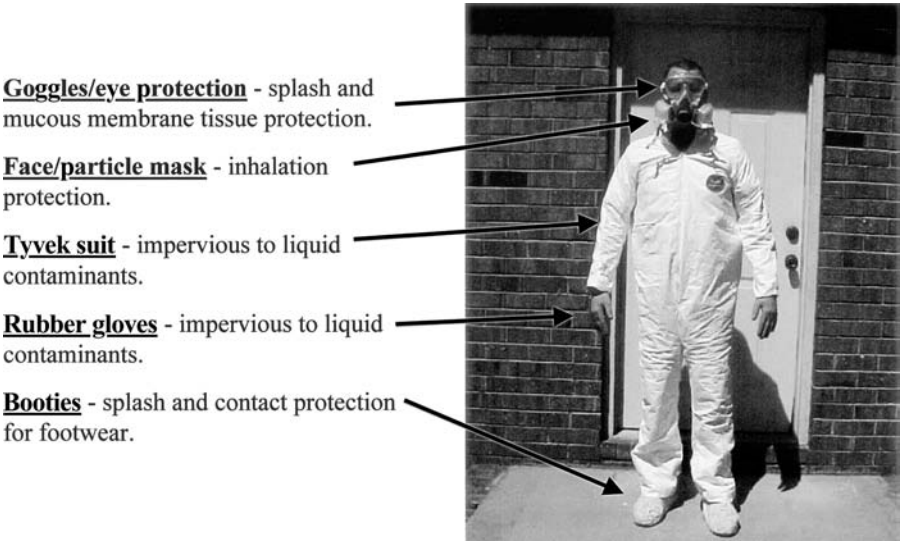

Figure 13.1 Personal protective equipment (PPE) serves to reduce the risk of the crime scene technician or analyst coming in contact with various crime scene threats. The minimum requirements for PPE in a bloodstain scene are gloves, booties, and a tyvek-type suit. During high-risk activities, such as scraping dried stains or moving significantly bloodied objects, additional measures such as eye goggles and filtration masks may be necessary.

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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.[7]

To reduce the risk from subsequent incidental contact with contaminated items outside of the crime scene, the analyst must control the collection of contaminated articles and protective clothing used at the scene. A single, controlled collection point prevents these articles from contaminating other areas and equipment. At the collection point, articles are discarded into biohazard bags and destroyed in an appropriate fashion. Generally, a local hospital can deal with the small amount of biohazard materials resulting from the crime scene processing, but we suggest coordinating such support before the need arises.

After use in the scene, any nondisposable clothing or equipment should be thoroughly cleaned. Although common, use of items such as favorite pens and notebooks increases the risk to the analyst. These items are not discarded and remain in close contact with the individual over extended periods. To avoid accidental contamination of such items, consider using only disposable items inside the scene.

For those items of equipment and clothing that require cleaning or laundering, bleach is the most effective disinfectant method. Bigbee reported that HIV is very susceptible to common forms of disinfectants and suggested cleaning solutions of household bleach and water mixed in a 1:9 or 1:10 dilution.[8] He adds the caution that either bleach or alcohol solutions may be used, but never together.

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, however, as a basic response to accidental exposure. First of all, remember that all exposure situations should be promptly reported to both medical personnel and employers.

As far as vaccination prevention goes, some level of prevention is possible in terms of the hepatitis B virus. Currently a three-shot vaccination is available. This vaccination is highly recommended for anyone who works in bloody scenes. OSHA Regulation 1910.1030 — Bloodborne Pathogens requires some public safety employers to provide this vaccination free of charge to at-risk employees who request it. Unfortunately, no such vaccination exists for HIV at this time.

In situations of on-scene injuries where accidental exposure to blood or body fluids occurs, the analyst should allow the wound to bleed freely for a few moments. Afterwards (or in cases of simple contact), wash the affected

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area immediately with antimicrobial detergent or a solution of 50 to 70% isopropyl or ethyl alcohol. Obviously, this action depends on the area injured or affected. Allow the solution to remain in place for a minimum of 1 min. Finally, wash and rinse the wound or affected area with liquid soap and water, then promptly seek medical attention.

Packaging Biohazard Evidence

As discussed in Chapter 9, proper packaging of serology evidence ensures that no loss of evidence occurs. Proper packaging also effectively eliminates subsequent contamination risks to those who must handle the evidence.

There are two basic packaging methods: paper and plastic. Clothing and other bloodstained items are generally packaged in paper products to ensure the samples do not degrade. In these instances the blood can seep through the paper prior to drying. Even if completely sealed, such seepage may represent a possible avenue of exposure.

As a result 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. In the end, the analyst or police department must consider both the evidential considerations and the exposure risks, 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 these purposes comes from blood banks, the analyst should apply universal precautions and consider all products contaminated.

A recent development has been 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.[9] Neither HIV nor the hepatitis B virus is transmitted through animals such as horses, cows, and sheep. Although such animals may harbor other pathogens (e.g., brucellosis), these

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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.

Other Sources of Information on Managing Bloodborne Pathogen Risks

The discussion of the problem and issues related to bloodborne pathogens in this chapter is very general. In seeking to establish a comprehensive risk management policy, you should obtain further guidance from the many documents that provide a more in-depth discussion of the subject. 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 help establish 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

Summary

The danger that law enforcement personnel and analysts face from bloodstained scenes is not likely to be eliminated in the near future. Processing a scene demands that someone come in contact with the evidence, and contact means 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 to 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, simply pattern any treatment plan on the advice of health care professionals.

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Appendix A

Weight/Measure Conversion Table

To Convert	Multiply By	To Get	Symbol
	Linear Measure		
Inches	25.4	Millimeters	mm
Inches	2.54	Centimeters	cm
Feet	30	Centimeters	cm
Yards	0.9	Meters	m
Millimeters	0.04	Inches	in
Centimeters	0.4	Inches	in
Meters	3.3	Feet	ft
Meters	1.1	Yards	yd
	Liquid Measure		
Fluid Ounces	30	Milliliters	ml
Quarts	0.95	Liters	l
Gallons	3.8	Liters	l
Microliters	0.001	Milliliters	ml
Milliliters	1,000	Microliters	µl
Milliliters	0.03	Fluid Ounces	fl. oz.
Liters	1.06	Quarts	qt
Liters	0.26	Gallons	gal
	Weight		
Ounces	28	Grams	g
Pounds	0.45	Kilograms	kg
Grams	0.035	Ounces	oz
Kilograms	2.2	Pounds	lb

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Appendix B

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 properly consider 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.

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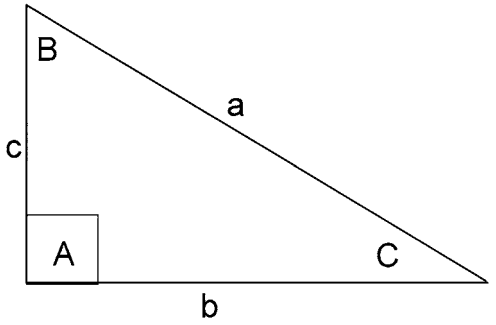

Figure B.1 A right triangle is any triangle in which one angle measures 90°. In this figure, angle A is 90°.

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:

$$\sin C = \frac{\text{opposite}}{\text{hypotenuse}} \text{ or } \frac{c}{a}$$

$$\tan C = \frac{\text{opposite}}{\text{adjacent}} \text{ or } \frac{c}{b}$$

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 5 to 7°. Table B.1 is an abbreviated trigonometric function table, in increments of 5°.

Let's 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:

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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

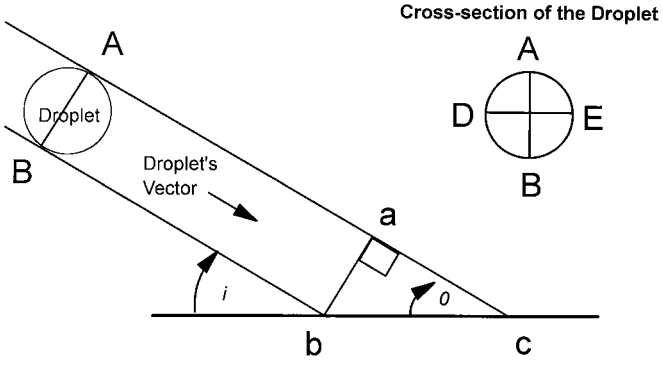

Figure B.2 The path at which a droplet strikes a target in combination with the target defines the right triangle abc. Using this triangle, we can draw an analogy between the dimensions of the resulting stain and the triangle, which allows the analyst to define the impact angle.

- 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.

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

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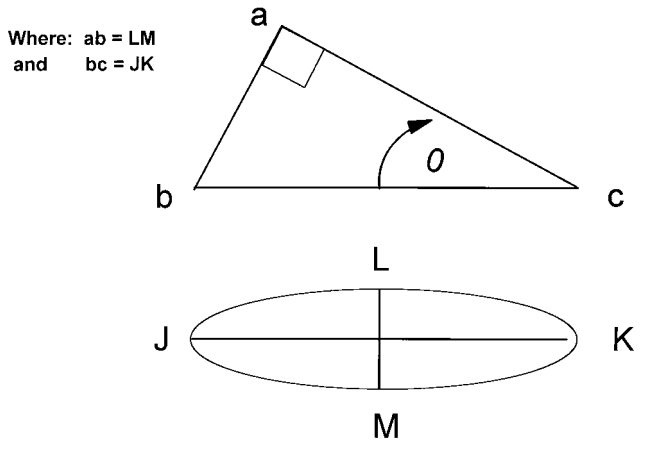

Figure B.3 The relationship we draw between the resulting stain and the right triangle. The side opposite (line ab) is analogous to the width of the stain (line LM). The hypotenuse (line bc) is analogous to the length (line JK).

(bc) and the length of our stain (JK), and the width element of the stain (LM) to the side adjacent (ab). Using the measurements of JK and LM in the stain, we can define the angle at *0*, where:

$$\sin 0 = \frac{\text{opposite}}{\text{hypotenuse}} \text{or} \frac{ab}{bc} \text{or} \frac{lm}{jk}$$

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 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 the angle *c* and line AD is the side adjacent 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.

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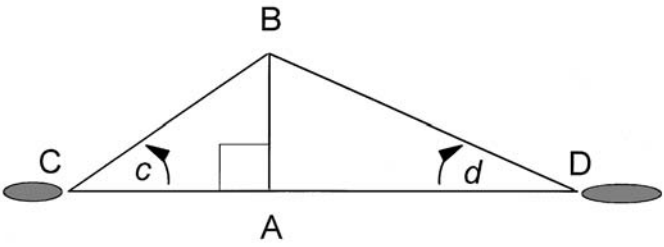

Figure B.4 The relationships of our scene to another right triangle when using the tangent formula. The probable point above the target where the stain originated is defined by the line AB. The line AC is equal to the distance from the base of Stain C to the point of convergence (A). The angle *c* is the impact angle for Stain C.

If we wish to solve for the angle *c* in Figure B.4, the tangent function tells us that for every right triangle:

$$\tan C = \frac{\text{opposite}}{\text{adjacent}} \text{ or } \frac{AB}{AC}$$

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

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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 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 ±7°. Not everyone will agree with that limit of uncertainty, but ranges of uncertainty for the accuracy of impact angle determinations are usually given between 5 and 7°.

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 (±7°) tells us the answer is estimated to the second digit (e.g., 4). Recognition of the significant digit in an equation's answer is a recognition of the overall uncertainty of the answer itself. To be objective, analysts must keep in mind the effects of accuracy and

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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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Appendix C

Stop-Motion Photography Techniques

In order to study droplets and impacts in depth, it is imperative that we photograph them. Unfortunately, that is not easily accomplished under ordinary circumstances. The action is far too fast. Tom Bevel and Leonard Conn, formerly with the University of Oklahoma Police Department, perfected a trigger mechanism that allows the researcher to use bulb settings on a camera with a strobe flash to capture these impacts.[1]

The process is relatively simple. In near-darkroom conditions, a light beam is set up to illuminate a small phototransistor. The beam is placed in such a way as to cross an area where the initiating action will occur. For example, it might be placed so that a blood droplet crosses the light beam, or the closing of a mousetrap device crosses the beam. The method of initiation is limited only by the desires of the researchers and the nature of the event they wish to photograph (e.g., low-velocity droplets or impact spatters).

As long as the beam illuminates the transistor, the circuit to the flash unit remains open. Once the beam of light is interrupted, this closes the circuit, causing the flash to fire.

Two potentiometers allow the researcher to adjust the time to the flash. The two potentiometers used are a 550K ohm, which allows for coarse adjustments, and a 50K ohm, which allows for fine adjustments. Using these controls, the researcher can adjust the time between the beam interrupt and the flash in increments of 10 to 560 ms.

To expose photographs, the researcher places the camera on the bulb setting and locks the shutter open. The droplet or mousetrap is then released, which interrupts the beam, initiating the flash. Once the photograph is exposed, the researcher closes the shutter. The trigger mechanism provides for approximately a 0.5-s delay before the flash can fire again. This gives the analyst sufficient time to close the shutter without risking a double exposure.

Synchronization of the flash to the action one wishes to capture is the most difficult part of the process. Before wasting film, researchers should practice and ensure the image captured is the one intended. This "practice" technique is relatively simple to master. The researchers simply focus their

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eyes on the area in which the action will occur. The droplet is released and the flash goes off. After a few attempts, individuals observing this are able to see well enough to get a good indication of the image they'll end up with.

Parts required for this device include:

3 in. × 2 in. × 1.5 in. plastic housing box
3 in. × 2 in. perforated board
Phototransistor RS-276-145 (Q1)
4093BCN or RCA SK4093B (IC1)
C106D2 SCR or RCA SK 3598 (SCR1)
1K-ohm resistor (R1)
3.3K-ohm resistor (R2)
10K-ohm resistor (R3)
330K-ohm resistor (R4)
680K-ohm resistor (R5)
550K-ohm potentiometer (R6)
50K-ohm potentiometer (R7)
1-mfd/35-colt capacitors (C1, C2)
Male PC sync cord

The parts are arranged as indicated in Figure C.1. At the time of this writing, total costs were under $30.

Reference

1. Bevel, Tom and Conn, Leonard, Stop Motion Photography of Bloodstains, *International Association of Bloodstain Pattern Analysts News*, July 1987.

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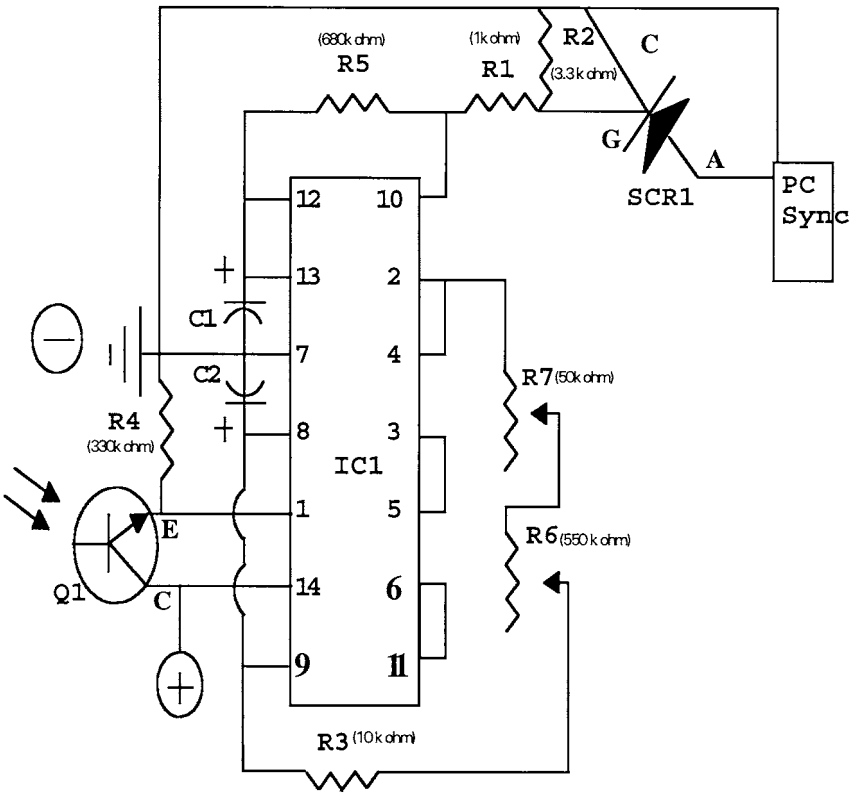

Figure C.1 The wiring diagram for a flash trigger mechanism.

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