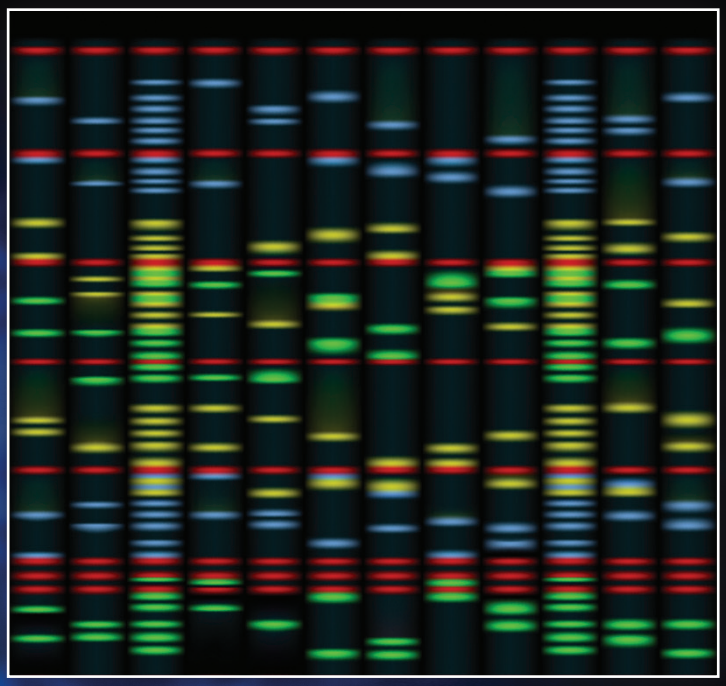


RICHARD LI

FORENSIC BIOLOGY

SECOND EDITION

CRC Press
Taylor & Francis Group

FORENSIC BIOLOGY

SECOND EDITION

RICHARD LI

John Jay College of Criminal Justice
New York, New York, USA

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Version Date: 20140818

International Standard Book Number-13: 978-1-4398-8972-5 (eBook - PDF)

Contents

SECTION II Basic Techniques in Forensic Biology

SECTION III Identification of Biological Evidence

Preface

Since the first edition of this book, new developments in forensic biology have led to a rapid expansion of the knowledge of the field. Therefore, it is necessary to create a new edition. This edition provides updates in most chapters of the original edition. Additionally, three new chapters (Chapters 2, 16, and 17) have been added and approximately 200 new figures have been created for this edition. Just like the first edition of this book, the new edition aims to inspire an undergraduate audience to tackle new challenges in the forensic biology field. It is written specifically to provide a general understanding of forensic biology and assist students in becoming more knowledgeable about the field of forensic biology and the wealth of available information. My readers should find that this edition of the book contains useful information, presented in a way that is more easily understood. Hopefully, it will be utilized by students, particularly those interested in forensic biology, to further enhance their education and training. I will continue to be open to suggestions in the future.

Richard C. Li
John Jay College of Criminal Justice
City University of New York
New York, NY

Acknowledgments

Many people contributed to this book. I would like to thank my family members for their support during the many hours I spent sitting in front of my computer. I would like to thank Jan Li for spending numerous hours assisting with the completion of this book by handling tasks such as image preparation and text editing. I would also like to thank Zully Santiago and Robert Greco for their proofreading of the manuscript. Additionally, I must acknowledge that my students at John Jay College of Criminal Justice provided excellent comments, suggestions, and even a few criticisms. The editorial and production staff at Taylor & Francis Group should also be acknowledged for their contributions. I would like to thank Mark Listewnik and Becky Masterman, senior acquisitions editors, for excellent suggestions and support, as well as project editor Richard Tressider for helping to keep the project on track. I would also like to thank Michelle van Kampen, project manager at Deanta Global Publishing Services, for overseeing the production of the book.

Author

Richard Li earned his MS in forensic science from the University of New Haven and his PhD in molecular biology from the University of Wisconsin–Madison. After completing his PhD, Dr. Li was awarded a postdoctoral fellowship at Weill Medical College of Cornell University and subsequently worked as a research faculty member at the School of Medicine of Yale University. Dr. Li has served as a criminalist at the Department of Forensic Biology, the Office of Chief Medical Examiner of New York City. For the past decade, he has held faculty positions in forensic science programs in the United States. Currently, Dr. Li is an associate professor of forensic biology at John Jay College of Criminal Justice. Additionally, he serves as a faculty member for the PhD program in forensic science for the college. Dr. Li's current research interests include the identification and analysis of biological specimens that are potentially useful for forensic investigations.

Introduction

This text defines forensic biology as analyses performed in the forensic biology sections of forensic laboratories and thus focuses on forensic serology and forensic DNA analysis. The aim of this book is to emphasize the basic science and its application to forensic science in an effort to make the principles more understandable. In addition, it introduces the language of forensic biology, thus enabling students to become comfortable with its use, and it provides clear explanations of the principles of forensic analysis.

To convey a general understanding of the concepts of forensic biology, it is necessary to include explanations of various techniques that are utilized in the field. The intent is to provide students with a scientific grounding in the area of forensic biology by offering an introduction to methods and techniques utilized by forensic biology laboratories. The techniques introduced in this text are accompanied by brief background descriptions and discussions of basic principles and techniques. Schematic illustrations are included where necessary. The text also acknowledges the benefits and limitations that apply to forensic biology techniques. Forensic techniques that were used in the past are also described. Learning past examples of forensic tests can help students to review historical forensic cases.

This text contains five modules, organized by section: Section I, Biological Evidence (Chapters 1–4); Section II, Basic Techniques in Forensic Biology (Chapters 5–11); Section III, Identification of Biological Evidence (Chapters 12–17); Section IV, Individualization of Biological Evidence (Chapters 18–23); and Section V, Forensic Issues (Chapters 24–26). The 26 chapters are designed to be covered in a single-semester course.

SECTION I

Biological Evidence

1

Crime Scene Investigation of Biological Evidence

A forensic investigation involving biological evidence usually begins at the crime scene. The crime scene investigation process includes maintaining scene security, preparing documentation, and collecting and preserving physical evidence. A crime scene investigation requires teamwork and effort. Each team member should be assigned specific tasks (Figure 1.1).

1.1 Protection of Crime Scene

A crime scene investigation begins with the initial response to a scene (Figure 1.2). Securing and protecting the scene are important steps in a crime scene investigation (Figures 1.3 through 1.6), and this task is usually carried out by the first responding officer arriving on the scene. The entry of authorized personnel admitted to the scene should be documented using a log sheet (Figure 1.7). Suspects, witnesses, and living victims should be evacuated from the scene. If a victim is wounded, medical attention should be sought.

Appropriate supplies and devices should be used to prevent the contamination of evidence by investigators. Protective wear and devices including a face mask or shield, safety eyeglasses, a disposable coverall bodysuit, gloves, shoe covers, and a hairnet should be used (Figures 1.8 and 1.9). Exposure to bodily fluids may occur during a crime scene investigation. An investigator can be exposed to bodily fluids through the mucous membranes, skin exposure, and needlestick injuries (especially when investigating a clandestine drug laboratory scene). Therefore, biosafety procedures must be followed for the protection of personnel from infectious blood-borne pathogens such as the human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV); infectious aerosol tuberculosis pathogens; and other biohazardous materials.

1.2 Recognition of Biological Evidence

A preliminary survey should be carried out to evaluate potential evidence. In particular, the recognition of evidence plays a critical role in solving or prosecuting crimes. The priority of the potential evidence at crime scenes should be assessed based on each item's relevance to the solution of the case. Higher priority should be assigned to evidence with probative value to the case. For example, the evidence related to a *corpus delicti* is considered to be of the highest priority. *Corpus delicti* is a Latin term meaning "body of crime." In Western law, it primarily refers to the principle that in order for an individual to be convicted, it is necessary to prove the occurrence

Figure 1.1 A crime scene investigation team. (© Richard C. Li.)

Figure 1.2 A crime scene unit vehicle that is used to respond to crime scenes. This type of vehicle is usually outfitted with devices and supplies that investigators need when processing a crime scene, as well as evidence packaging materials, fingerprint collection kits, and DNA collection kits. Additionally, it can be equipped with a workstation for computer access, a refrigerator for storing chemicals, and a compact fuming hood for processing latent fingerprints, as well as equipment cabinets and drawers. (© Richard C. Li.)

Figure 1.3 Crime scene barrier tape is used to ensure that only investigators are admitted to the scene. (Courtesy of H. Brewster.)

Figure 1.4 A police officer guards the crime scene. (© Richard C. Li.)

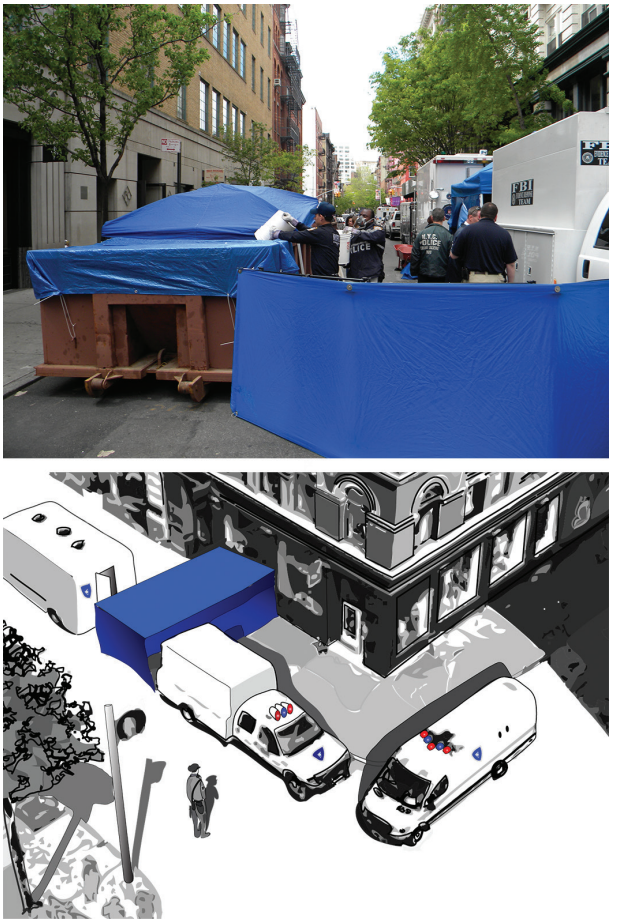
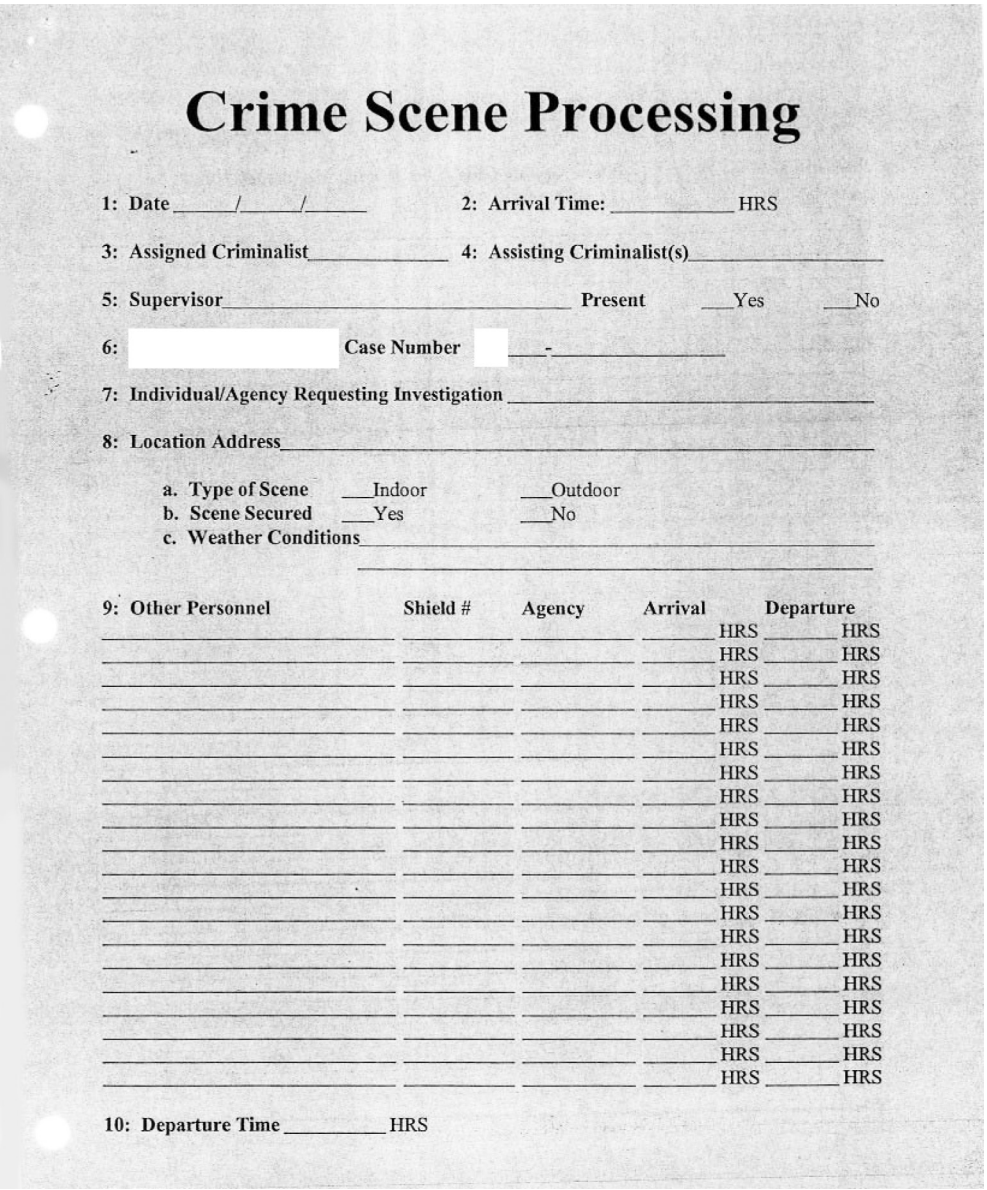


Figure 1.5 Crime scene privacy screen and tent. The screen (top) and the tent (bottom) are useful devices for shielding the evidence or body from viewing by unauthorized personnel. (© Richard C. Li.)

Figure 1.6 Barricades are set up to keep crowds at a distance from the scene. (© Richard C. Li.)

of the crime. In a forensic investigation, it also refers to the physical evidence proving that a crime was committed. For example, when an individual is missing, a missing persons investigation is usually initiated. If *corpus delicti*, such as a dead body or a victim's blood at a crime scene (Figure 1.10), is discovered during the investigation, a homicide case can be established and a suspect can be charged with homicide. Higher priority should also be attached to evidence that can establish connections such as *victim-to-perpetrator linkage*. For example, items found in a perpetrator's possession may be linked to a victim. This also applies to transfer evidence based on the principles of transfer theory, also known as the *Locard exchange principle*, which theorizes that the cross-transfer of evidence occurs when a perpetrator has any physical contact with an object or another person (Figures 1.11 through 1.14). Thus, trace evidence, such as hairs and fibers, may be transferred from a perpetrator to a victim or vice versa. This explains why it is important to ensure that perpetrators and their belongings are thoroughly searched for trace evidence. Likewise, victims and their belongings should be examined for the same reason.

Victim-to-scene and perpetrator-to-scene linkages can also be established. Blood belonging to a perpetrator or a victim found at a crime scene can establish such a linkage (Figure 1.15). Additionally, reciprocal transfers of trace evidence from crime scenes can be used to link a suspect or a victim to a crime scene. A perpetrator may present a unique *modus operandi* (MO). *Modus operandi*, a Latin term commonly used in criminal investigations, refers to a particular pattern of characteristics and the manner in which a crime is committed. For example, Richard Cottingham, a serial killer known as "the torso killer," dismembered his victims and took their limbs and heads with him but left their torsos at the scene. He then set the rooms on fire before



Crime Scene Processing

1: Date_____/_____/_____ 2: Arrival Time: _____ HRS

3: Assigned Criminalist_____ 4: Assisting Criminalist(s)_____

5: Supervisor_____ Present ___Yes ___No

6: _____ Case Number ____-_____

7: Individual/Agency Requesting Investigation _____

8: Location Address_____

a. Type of Scene ___Indoor ___Outdoor
b. Scene Secured ___Yes ___No
c. Weather Conditions_____

9: Other Personnel	Shield #	Agency	Arrival	Departure
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS
			HRS	HRS

10: Departure Time _____ HRS

Figure 1.7 An example of a log sheet for documenting authorized personnel at a crime scene. (© Richard C. Li.)

fleeing the scenes. Evidence that provides information on the MO is also vital to an investigation. A distinct MO can establish a *case-to-case linkage* for serial offender cases.

1.3 Searches

Some investigations require a search for specific items of evidence such as biological stains, human remains, and all relevant evidence. A search usually has a specific purpose. Thus, the use of search patterns can be helpful, especially in cases involving large outdoor crime scenes.

Figure 1.8 Personal protection wear and devices that are used at crime scenes. (© Richard C. Li.)

Figure 1.9 Disposable glove (left) and glove with extended cuff (right). (© Richard C. Li.)

Search patterns may include a grid, line, or zone (Figures 1.16 and 1.17). The method that is ultimately used depends on the type and size of the scene (Figures 1.18 through 1.20). Additionally, the points of entry and exit and the paths followed by a perpetrator should also be searched.

Searching for biological stains usually utilizes devices such as an alternate light source (ALS); see Figures 1.21 and 1.22. An ALS either produces a single specific wavelength of light or a desired wavelength by using specific filters. Biological materials such as blood, semen, and saliva emit fluorescent light under an ALS, which can facilitate the locating of biological materials. Additionally,

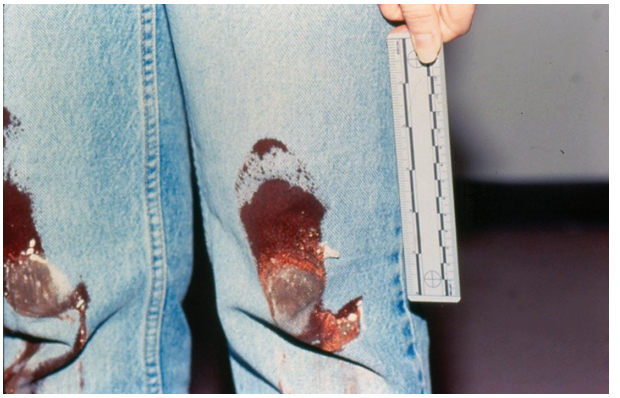


Figure 1.10 Photographic documentation of bloodstains on clothing. (© Richard C. Li.)

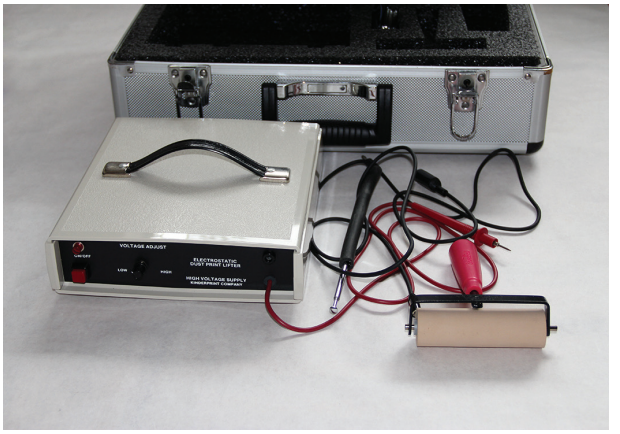


Figure 1.11 An electrostatic dust print lifting device can be utilized for processing impression evidence such as footprints and tire tracks. (© Richard C. Li.)

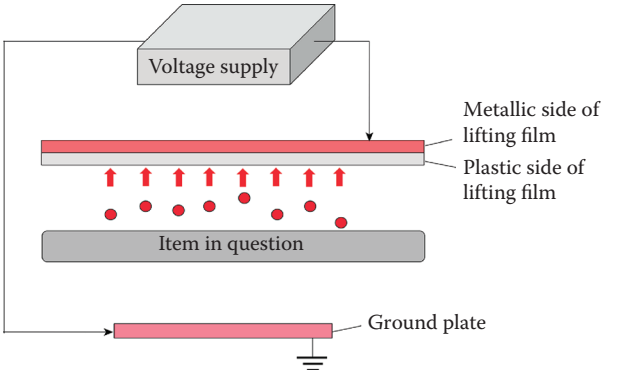


Figure 1.12 Basic components of an electrostatic dust print lifting device. The lifting film is placed on top of the item in question with the plastic side against the surface and the metallic side facing up. A ground plate is placed directly on the ground. The lifting film and ground plate are connected to the voltage supply apparatus. Once the charging voltage is turned on, the static charge transfers the dust particles from the surface to the plastic side of the lifting film. (© Richard C. Li.)

Figure 1.13 A high-intensity light-emitting diode (LED) device for locating evidence at a crime scene is particularly effective in highlighting trace evidence such as hairs, fibers, and shoe prints. (© Richard C. Li.)

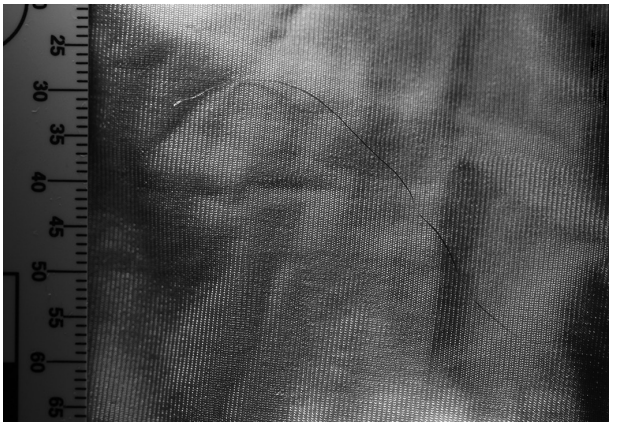


Figure 1.14 A hair found on a victim's clothing can be transferred evidence from a suspect. (© Richard C. Li.)

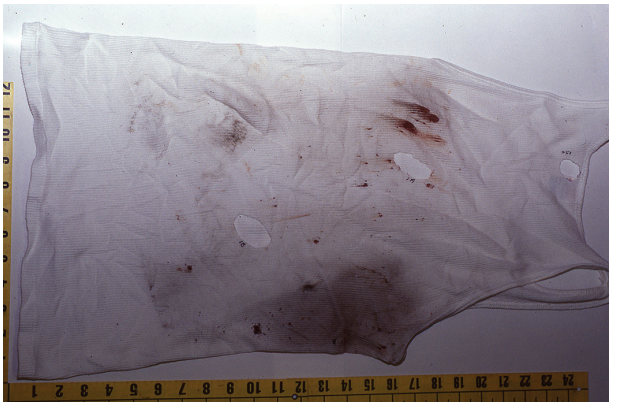


Figure 1.15 Finding a victim's blood on a suspect's clothing can establish a link between them. (© Richard C. Li.)

Figure 1.16 Grid search pattern for an outdoor scene. The investigators and anthropologists present are searching for human bone evidence within the grid. (Courtesy of H. Brewster.)

Figure 1.17 Line search pattern for an outdoor scene. (Courtesy of H. Brewster.)

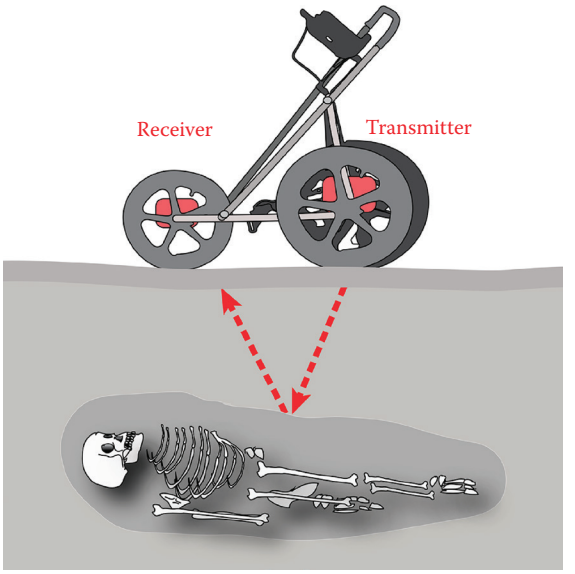


Figure 1.18 Using ground-penetrating radar (GPR) to locate clandestine graves of homicide victims. GPR uses electromagnetic waves emitted from a transmitter, which are detected by a receiver to locate clandestine burials and buried objects such as weapons embedded in soils. Images of the potential evidence are typically obtained by moving the antenna of the GPR device over the surface of the ground. (© Richard C. Li.)

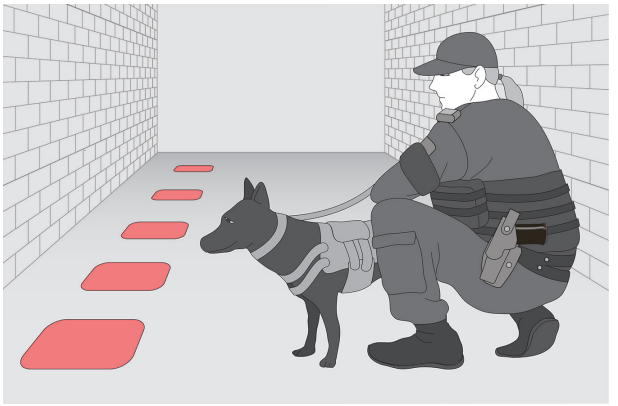


Figure 1.19 Using cadaver-sniffing dogs to alert investigators to the presence of buried bodies. The odor produced by the decomposition of the human body may be sensed by cadaver-sniffing dogs. Odor-absorbing pads absorb and retain the scent of decomposed remains and can be placed at the scene for several days. Upon sniffing the pads, a cadaver dog may indicate the presence of buried human remains or may indicate that human remains were once buried in that location. However, it is not clear that this technique is reliable. (© Richard C. Li.)

Figure 1.20 Tracking dog for searching suspects. In a situation of processing a recent crime scene when the suspect may be in close vicinity to the scene, a tracking dog can be used. A tracking dog, such as a bloodhound, can potentially follow the scent from items left at the scene to locate a suspect nearby. (© Richard C. Li.)

Figure 1.21 Compact alternate light source devices, which are intended specifically for use at crime scenes, reduce search time and improve the recovery of evidence such as biological evidence and chemically enhanced latent fingerprints. (© Richard C. Li.)

Figure 1.22 LED light sources provide illumination for locating evidence such as bodily fluid stains, hair, or fibers. (© Richard C. Li.)

Figure 1.23 An example of a compact Rapid DNA device for processing DNA evidence in the field. (© Richard C. Li.)

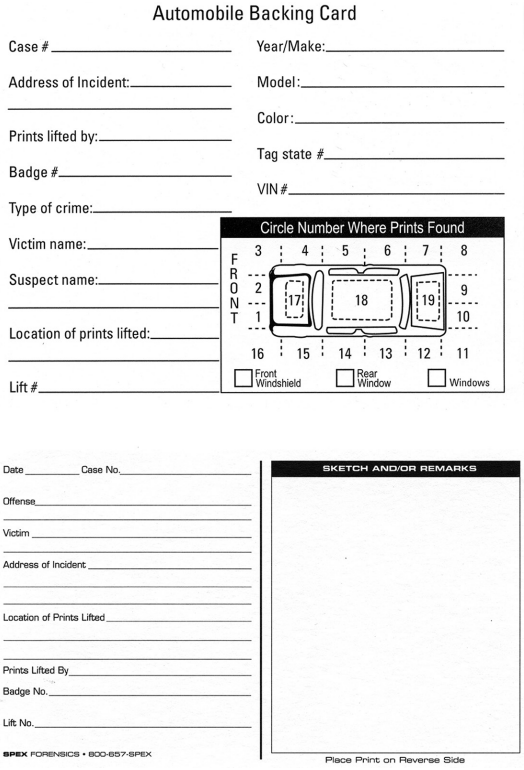


Figure 1.24 An example of sketch documentation. (© Richard C. Li.)

field tests and enhancement reagents can be used to facilitate crime scene searching (Chapter 12). These reagents can detect and identify biological evidence. The tests are very simple, rapid, and sensitive, and thus can be used at crime scenes. For example, phenolphthalin and leucomalachite green tests can be used for detecting blood evidence. Sometimes, minute amounts of blood may be

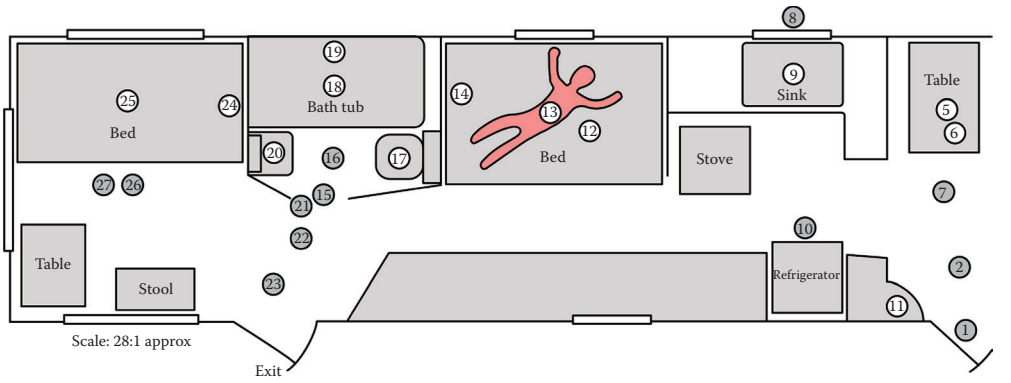


Figure 1.25 Sketches for documenting the sites of fingerprints. (© Richard C. Li.)

present at the scene as a result of attempts to clean up blood prior to the investigation. These stains may not be visible with the naked eye. Enhancement reagents such as luminol and fluorescein, which emit chemiluminant and fluorescent light upon reacting with certain biological materials, respectively, can be used. Additionally, the enhancement reagents can detect faint blood-containing pattern evidence such as faint bloody fingerprints, footprints, and other pattern evidence of physical contact such as drag marks in blood. However, precaution should be taken since these reagents are not usually very specific to blood. Certain substances such as bleach, various metals, and plants may also lead to chemical reactions with the field tests and the enhancement reagents. In these cases, the evidence collected is further tested with laboratory examination and analysis.

Recently, portable and field-deployable instruments have been developed that are capable of processing buccal swabs and potentially other evidence to produce a DNA profile on-site (Figure 1.23). It is a fully automated process, using the Rapid DNA technology (Chapter 8), that

Figure 1.26 A reflected ultraviolet imaging system (RUVIS) imager for documenting close-up views of evidence such as latent fingerprints. (© Richard C. Li.)

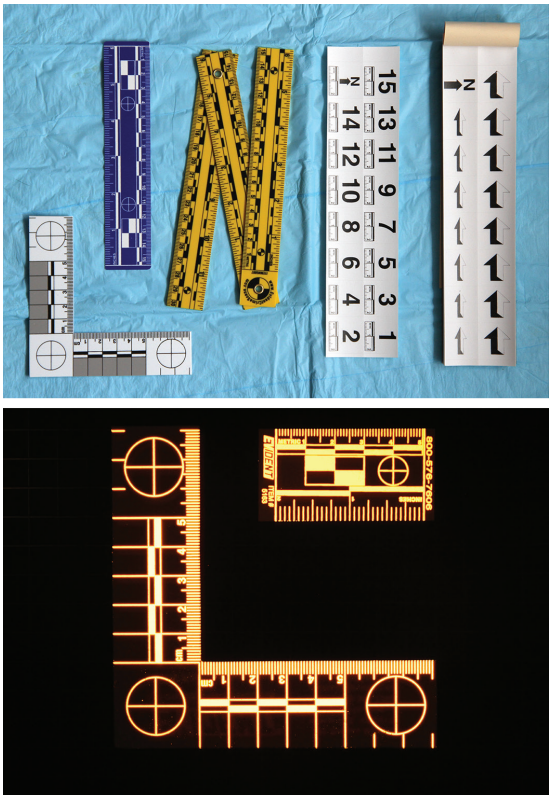


Figure 1.27 Scales for photographic documentation. Regular scales (top) can be used with visible light sources. Fluorescence scales (bottom) can be used for the documentation of fluorescing evidence after certain treatment, such as chemical enhancement, using alternate light sources. (© Richard C. Li.)

can be completed within 2 h by a trained crime scene investigator or police officer. These instruments may provide a new tool for expediting the identification of suspects and developing investigative leads at the scene. Additionally, this technology can enable law enforcement agents to rapidly determine whether the crimes were isolated incidents or part of serial crimes committed by the same offender, such as in serial burglary and arson cases. It can also be used in the identification of human remains in mass disasters.

1.4 Documentation

The conditions at a crime scene, including both the individual items of evidence and the overall scene, must be documented to provide vital information for investigators and for the courts. The most common documentation methods are drawing sketches and taking photographs and videographs. The sketch is to reflect the positions and the spatial relationships of items and persons with measurements using a scale. An investigator usually prepares a rough sketch first and later converts the rough sketch into a finished sketch (Figures 1.24 and 1.25). If bloodstains are present at the scene, the location of bloodstain patterns should be emphasized. Prior to handling and moving evidence, photographs should be taken with different views: an overall view of the entire scene, a medium-range view showing the positions and the relationships of items, and a close-up

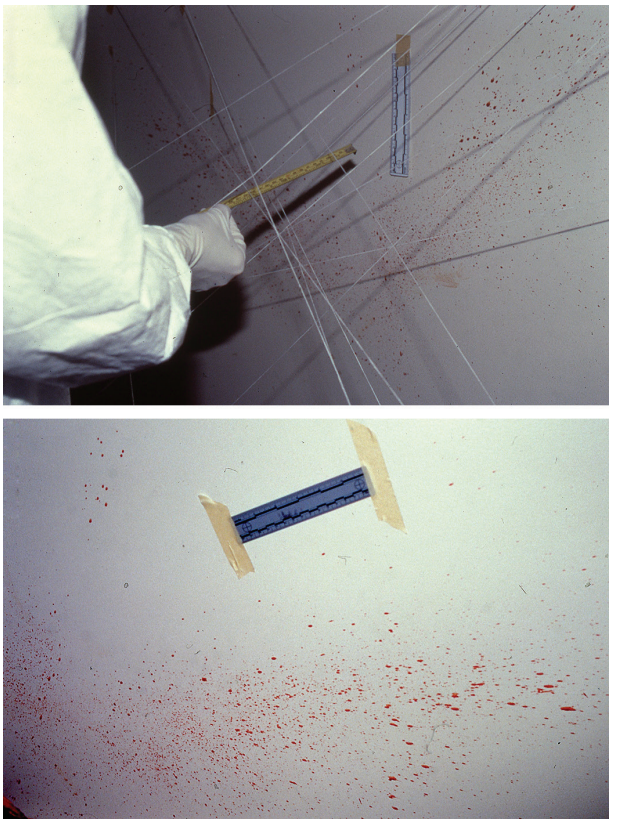
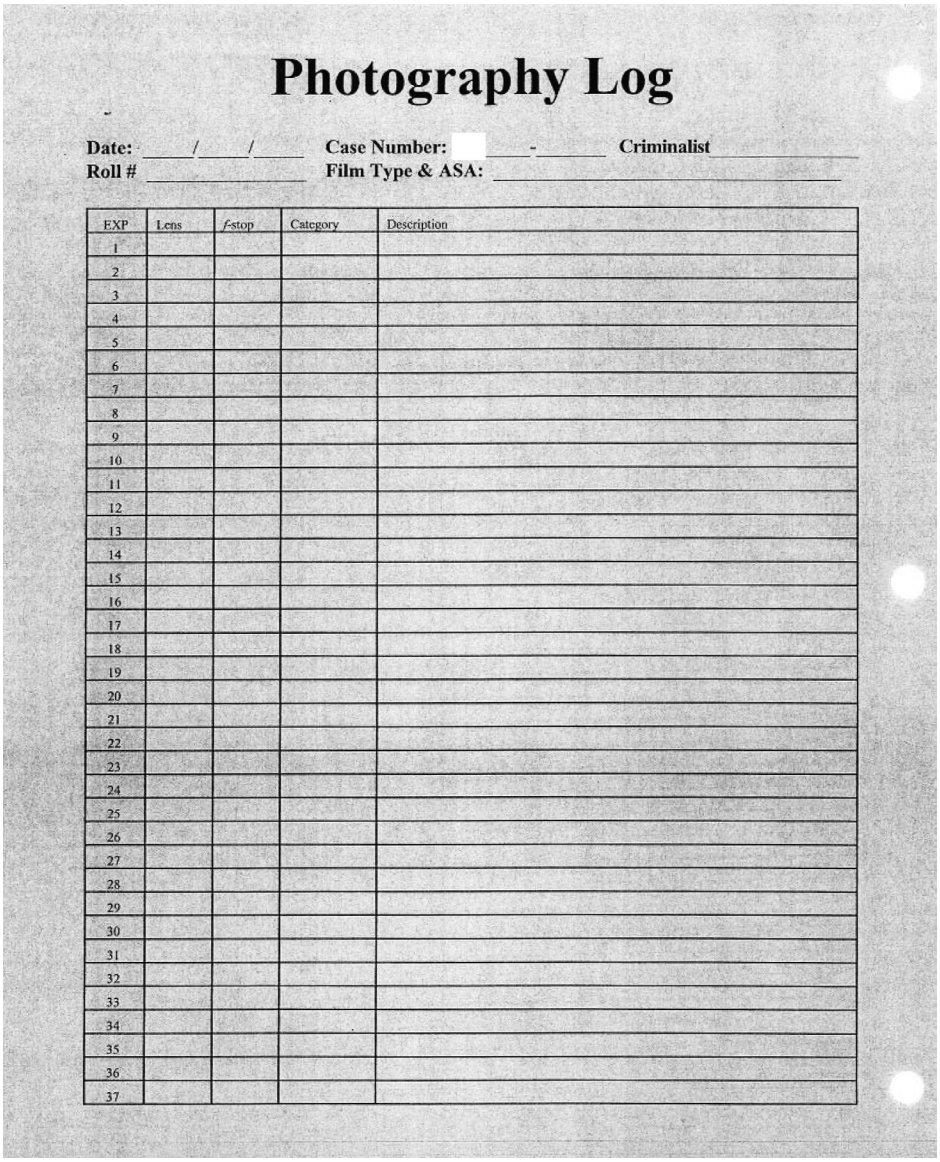


Figure 1.28 Photographic documentation of bloodstain patterns. (© Richard C. Li.)

view showing details of the evidence (Figure 1.26). Photographs should also include a measuring device such as a scale (Figure 1.27) to accurately depict the sizes of items such as bloodstains or bite marks. This can be achieved simply by placing a ruler adjacent to the evidence when it is photographed (see Figure 1.28). A photograph log sheet can be used to record the chronological order of crime scene photographs and to note filming conditions and any additional relevant information (Figure 1.29). Similar documentation should be prepared for videographs when appropriate. Additionally, written or audio-recorded notes can be used. Notes should include complete and accurate information of a crime scene investigation, such as the case identifier number, the identities of the investigators, and a description of the scene or items (e.g., location, size, and shape). Additionally, any disturbance of evidence occurring during crime scene processing should be noted.

1.5 Chain of Custody

Custody information should be recorded at each event when evidence is handled or transferred by authorized personnel. Usually, a custody form listing a specific evidence item is used to document the chain (Figure 1.30). Each individual who acquires custody of the evidence must sign a chain of custody document. An incomplete chain of custody may lead to an inference of possible tampering or contamination of evidence. As a result, the evidence may not be admissible in court.



Photography Log

Date: ____/____/____ Case Number: ____-_____ Criminalist _____
Roll # _____ Film Type & ASA: _____

EXP	Lens	f-stop	Category	Description
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				

Figure 1.29 Crime scene photography log. (© Richard C. Li.)

1.6 Collection of Biological Evidence

After the crime scene documentation is completed, the collection of evidence can be initiated. Small or portable items, such as bloodstained knives, can be collected and submitted to a crime laboratory (Figure 1.31). Large or unmovable items of evidence (Figure 1.32) can be collected and submitted in sections, such as a section of wall where bloodstains are located. Table 1.1 and Figures 1.33 through 1.38 summarize and illustrate representative collection techniques. Specific care is required for the collection of biological evidence in the following situations:

- *Bloodstain pattern evidence*: It is especially important to thoroughly document the bloodstain pattern evidence at a crime scene prior to collection. Bloodstain patterns can be especially useful in crime scene reconstruction.

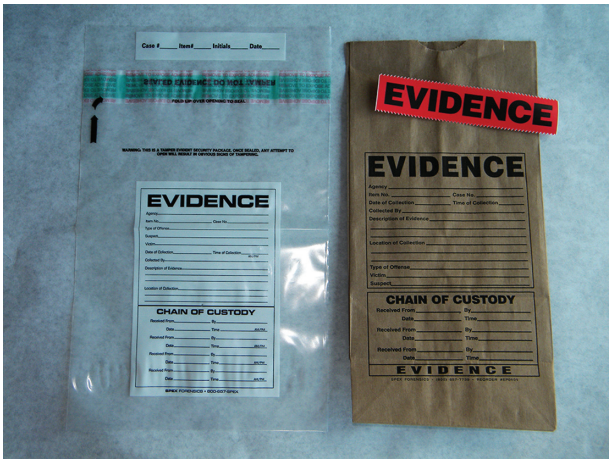


Figure 1.30 Labels with the chain of custody that are used for marking the evidence contained in the packaging. (© Richard C. Li.)

Figure 1.31 Handling sharp objects. Bloodstained knives collected and submitted to laboratories (top) and a box for packing sharp objects (bottom). (© Richard C. Li.)

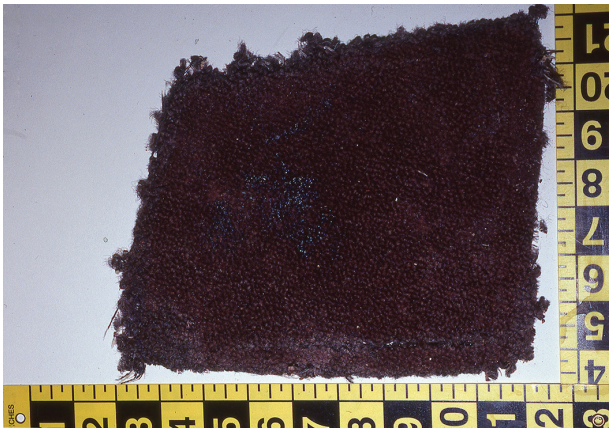


Figure 1.32 A section of bloodstained carpet is collected. (© Richard C. Li.)

- *Multiple analysis of evidence*: If multiple analyses are needed for a single item of evidence, nondestructive analyses should be carried out first. For example, a bloody fingerprint should be collected for ridge detail analysis prior to collecting blood for DNA analysis.
- *Trace evidence*: Trace evidence such as hairs and fibers can be present in bloodstained evidence and should be identified and properly collected.
- *Control samples*: Control (known or blank) samples should be collected from a control area (e.g., unstained area near a collected stain).
- *Size of stain*: Polymerase chain reaction (PCR)-based forensic DNA techniques are highly sensitive and allow for the successful analysis of very small bloodstains. All bloodstains, even if they are barely visible, should be collected at a crime scene.
- *Wet evidence*: Wet evidence should be air-dried (without heat) prior to packaging to prevent the degradation of proteins and nucleic acids, which are used for forensic serological and DNA analysis.

1.7 Marking Evidence

The marking of evidence is necessary for identification purposes so that it can be quickly recognized even years later (Figure 1.39). An investigator's initials, the item number, and the case number are usually included in marking. Information can be marked on a tag, a label attached to the item, or directly on garment evidence. The marking of evidence should not be proximal to bullet holes or biological stains to prevent the mark from interfering with analyses.

1.8 Packaging and Transportation

Packaging is intended to protect and preserve evidence. All evidence should be secured and protected from possible contamination. Fragile items should be protected to prevent any damage during transportation. Exposure to heat and humidity should be avoided to protect biological evidence from degradation during transport. Various packaging methods are available

Table 1.1 Methods for Collecting Biological Evidence

Type of Evidence	Condition	Method of Collection	Procedure
Blood	Dry	Swab	Best on nonabsorbent surfaces; lightly moisten sterile swab with distilled or sterile water, rub over stain while rotating; allow to air-dry; a combination of first a moistened swabbing followed by second a dry swabbing (both swabs submitted) is recommended
		Cutting	Cut stain from item
		Scraping	Scrape bloodstain into a clean piece of paper using a clean blade; wrap sample using druggist's fold
		Lifting	Works for nonabsorbent surfaces; use fingerprint lifting tape that does not interfere with DNA testing to lift stain; lifted stain should be covered with a piece of lifter's cover
		Collect entire item	Collect if item contains bloodstain pattern; difficult to swab; requires multiple exams
	Wet	Swab	Absorb blood sample onto sterile cotton swabs; stain should be concentrated on tip and allowed to air-dry
		FTA paper	Use a sterile disposable pipet to collect liquid blood; spot on FTA paper; allow to air-dry
	Reference liquid blood sample	Venous blood collection	Collect blood in a purple-topped vacutainer tube containing ethylenediaminetetraacetic acid (EDTA) anticoagulant; refrigerate but never freeze
Semen	Dry or wet	See "Blood" above	See "Blood" above
	Condom	Collect entire item	Secure condom with a tie and place in a container in a refrigerator; submit to laboratory as soon as possible
	Various conditions	Victim sexual assault kit	Standardized kit to collect biological evidence from the body of a victim includes swabs, microscope slides, and envelopes
	Various conditions	Suspect standard kit	Standardized kit to collect biological evidence from the body of a suspect includes swabs, microscope slides, and envelopes

(*continued*)

Table 1.1 (Continued) Methods for Collecting Biological Evidence

Type of Evidence	Condition	Method of Collection	Procedure
Victim vaginal fluid	Dry or wet	See "Blood" above	Often collected from a suspect's pubic area or fingers
Saliva	Dry or wet	See "Blood" above	Often collected from a bite mark or a victim's pubic area
	Reference saliva (buccal) samples	Swab	Swab the inside of the cheek using two swabs, rotating them during collection; allow swabs to air-dry
		Filter paper	Place donor saliva sample on marked area of filter paper; allow to air-dry
Hairs	Head and pubic hairs	Lifting	Refer to dry bloodstain lifting method
		Transfer	Use forceps to transfer hair onto a piece of paper that can be folded
		Vacuum	Vacuum can be used if necessary; generally not recommended
Fingernails and scrapings	Various conditions	Clipping	Use a clean clipper to clip nails onto clean paper; wrap samples using druggist's fold
		Scraping	Scrape undersides of nails onto clean paper; wrap samples using druggist's fold
Bones	Various conditions	Freeze in container	Collect if blood is not available; collect bone with marrow if available; rib bone and vertebrae are preferred; place specimen in a container and freeze if wet
Teeth	Various conditions	Container	Collect teeth with dental pulp if possible into a container
Tissues and organs	Wet	Freeze in a container	Collect if blood is not available; place specimen in a container and freeze
DNA database samples	Various conditions	Various	Follow jurisdiction protocol for collecting samples from arrested individuals or convicted offenders or both

Source: Fisher, B., *Techniques of Crime Scene Investigation*, 7th edn., 2004, CRC Press, Boca Raton; Lee, H.C. et al., *Henry Lee's Crime Scene Handbook*, 2001, Academic Press, San Diego; National Institute of Justice. Using DNA to solve cold cases, Special Report, 2002, US Department of Justice, Office of Justice Programs, Washington, DC.

Note: Samples requiring refrigeration or freezing are noted; other samples may be stored at room temperature. Dry evidence should be packed in a porous material such as paper (envelope, bag, box) as described in the text.

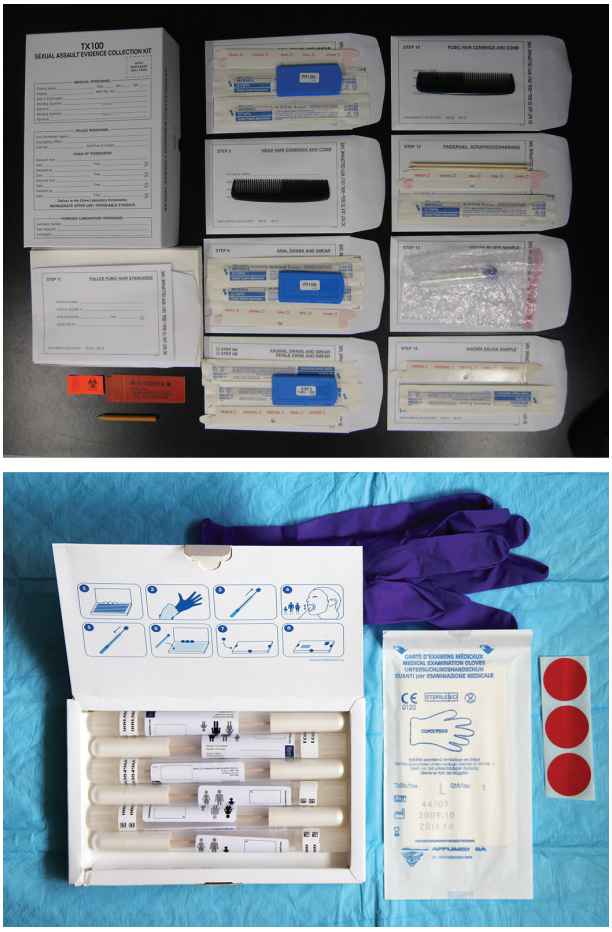


Figure 1.33 Evidence collection kits. Sexual assault evidence collection kit (top). Paternity evidence collection kit (bottom). (© Richard C. Li.)

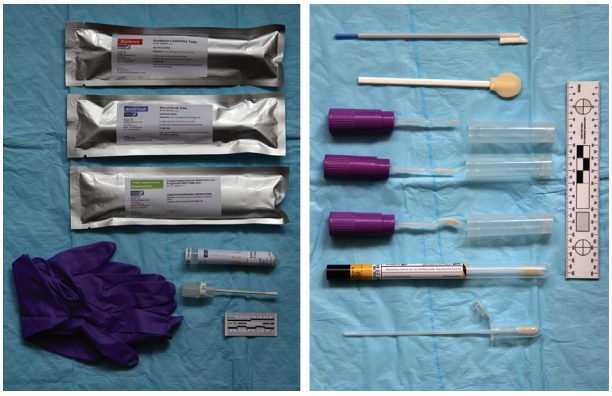


Figure 1.34 Various types of swabs that are used for collecting biological evidence. (© Richard C. Li.)

Figure 1.35 Fingernail swabbing for recovering evidence. Fingernail swabs are often collected from individuals who are involved in a struggle in violent crimes and in digital penetration in sexual assault cases. Fingernail swabs are sampled separately from both hands. (© Richard C. Li.)

depending on the type of evidence handled (Figures 1.40 through 1.42). The following are general considerations related to the packaging of evidence:

- *Evidence from different sources*: To prevent the transfer of evidence from different sources, items of evidence should not be grouped in a single package. However, evidence may be packed in a single container if the items were found together.
- *Folding of evidence*: Folding of clothing, especially items with wet bloodstains, can transfer evidence from one part of a garment to another. If a large, dry garment must be folded, a piece of clean paper should be placed between different parts of the garment to avoid direct contact between the different parts of the garment, thereby preventing the transfer of evidence.
- *Packing materials*: Envelopes, bags, and boxes that are made of porous materials such as paper are appropriate for packaging dry biological evidence. Dry, bloodstained evidence should not be sealed in plastic bags or containers that trap moisture.
- *Liquid evidence*: Tubes containing liquid such as blood should not be frozen because the volume of a liquid expands in freezing temperatures and this expansion may lead to cracking. Tubes should be placed in plastic bags to prevent leaks in case of

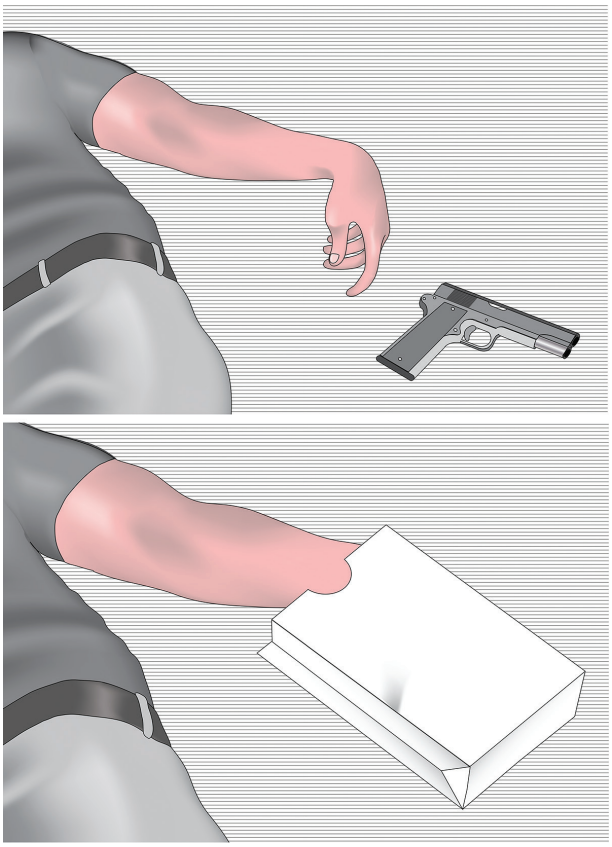


Figure 1.36 Hand bags for protecting the hands of a decedent in an alleged suicide. Gunshot residue can be found on hands after firing a weapon (top). The bagging of the hands, using paper bags and wide rubber bands, prevents the loss of gunshot residue during the transportation of the body (bottom). (© Richard C. Li.)

accidental breakage. Liquid evidence should be transported and submitted to a laboratory as soon as possible after the collection of evidence.

- *Trace evidence*: All such evidence should be wrapped in paper with a druggist's fold (Figure 1.43). The wrapped trace evidence can be packed in an envelope.

Packaged evidence should be properly labeled with a description of the evidence and sealed with evidence tape. It is important for the person packaging the evidence to initial and date across the seal to show authenticity (Figure 1.44). A seal should not be cut when a sealed evidence bag is opened. Instead, an opening can be created by cutting at an area distal from the existing seal. After analysis is complete, the evidence packaging should be resealed. Table 1.1 summarizes additional steps for packaging evidence.

1.9 Final Survey and the Release of the Crime Scene

During a final survey, a discussion with all personnel in the crime scene investigation team should be carried out to thoroughly review all aspects of the search. It is important to ensure

Figure 1.37 Blood cards are typically used for collecting blood evidence from a known source such as a suspect or a victim (top). A manual hole punch can be used to create a blood card punch for DNA extraction. Blood samples are air-dried on blood cards for storage (bottom). (© Richard C. Li.)

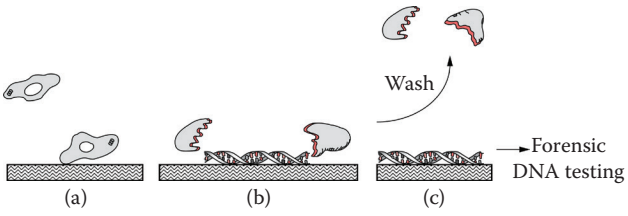


Figure 1.38 Application of Flinders Technology Associates (FTA) filter paper for the collection of biological evidence. (a) Biological fluid with cells is applied to FTA paper. (b) Cells are lysed and DNA is immobilized on FTA paper. (c) Cellular materials are washed away and DNA remaining on the FTA paper can be used for forensic testing. (© Richard C. Li.)

Figure 1.39 Photographic documentation of a knife. Note the evidence tag. (© Richard C. Li.)

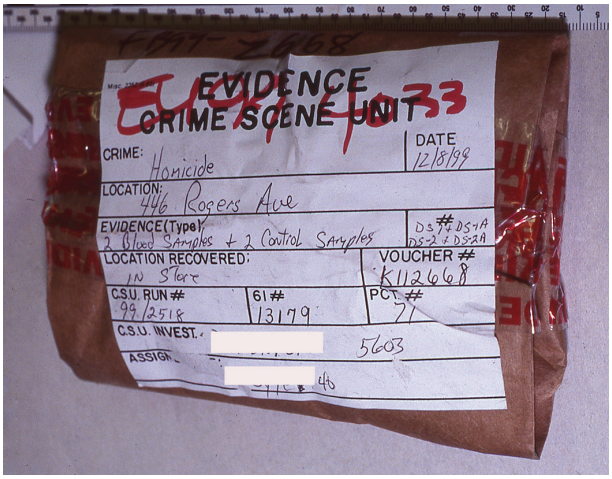


Figure 1.40 Evidence containing dried bodily fluid stains is packed in a paper bag. (© Richard C. Li.)

Figure 1.41 Alleged diluted blood collected from a pipe (left) and placed in plastic containers (right). (© Richard C. Li.)

Figure 1.42 Evidence pouch. The front of the pouch is transparent for viewing the content. The back of the pouch is made of breathable materials allowing wet evidence, such as swabs, to dry inside the pouch. (© Richard C. Li.)

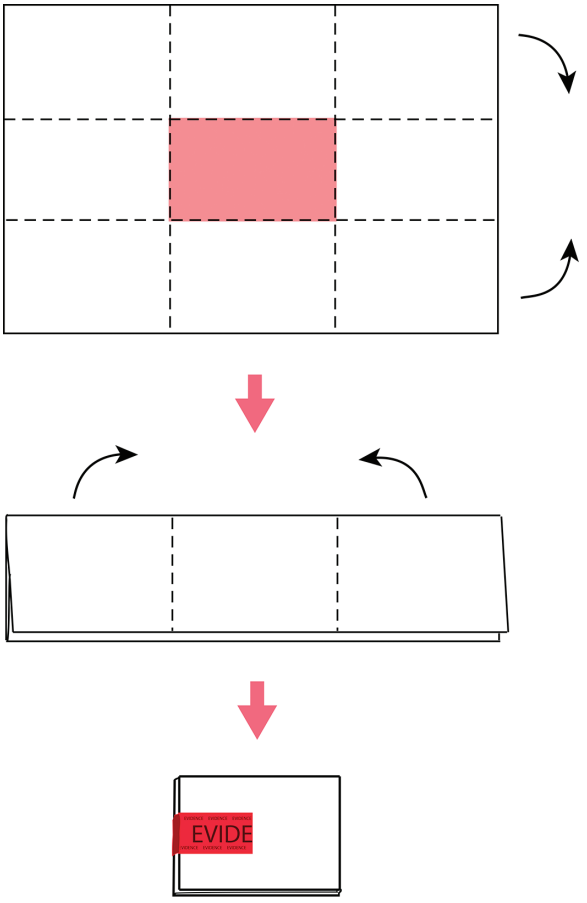


Figure 1.43 An example of a druggist's fold. Trace evidence should be deposited in the center (colored area) of the paper. (© Richard C. Li.)

Figure 1.44 Proper marking of sealed evidence. Note that the evidence packaging was cut a second time and resealed at a different location than that of the preexisting seal. (© Richard C. Li.)

that the scene has been searched correctly and completely, and that no area has been missed or overlooked. All documentation including the chain of custody document must be complete and all evidence should be collected, packed, documented, and marked. Photographs of the final condition of the scene should be taken. Once the final survey is completed, the crime scene can be released. Reentry into the crime scene may require a search warrant after the scene is released. Crime scene release documentation usually includes the time and date of release, to whom it is released, and by whom it is released.

1.10 Crime Scene Reconstruction

Crime scene reconstruction is the scientific process of determining the sequence of events and actions that occurred prior to, during, and after a crime. Reconstruction is carried out based on the information from the crime scene observations and the laboratory examination of physical evidence. The overall scientific process in reconstruction usually involves several steps. The process usually begins with the formulation of questions related to the problems that need to be solved. The questions can refer to the explanation of the specifics of the crime, for instance, "Where was the shooter's position when the shooting occurred?," "Where was the victim's position when shot?," and "What is the muzzle-to-target distance during the shooting?" In order to conduct a thorough crime scene reconstruction, all useful information is collected for review, such as photographs, videotapes, notes, sketches, autopsy reports, and analysis reports of the physical evidence. A hypothesis is then constructed based on the information obtained, which may explain the events and actions involved in a crime. The next step is making predictions that determine the logical consequences of the hypothesis. One or more predictions are selected for testing. The hypothesis is tested by conducting reconstruction experiments. One example of a reconstruction test is bloodstain pattern reconstruction in violent crimes (Chapter 2). Other examples of reconstruction may include trajectory and shooting, glass fracture, and accident reconstruction. The final step is to analyze experimental data and draw a conclusion. The experimental data are analyzed to see if the hypothesis is true or false. Additionally, the interpretation of physical evidence analysis, witness and confession statements, and investigative information should also be considered.

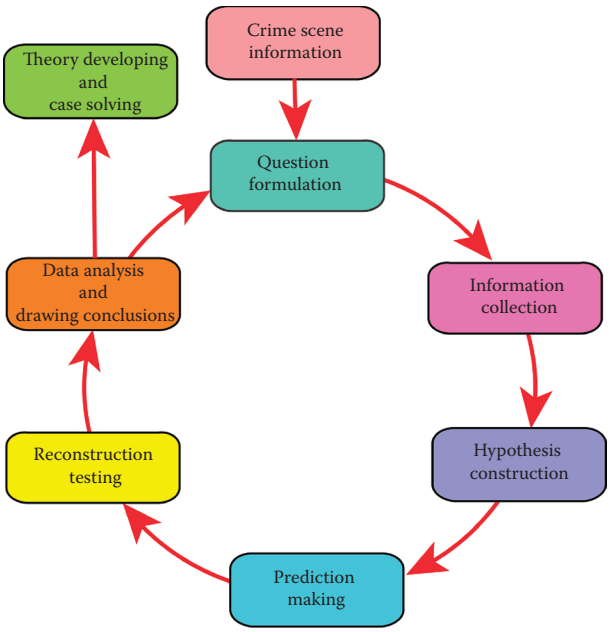


Figure 1.45 The scientific process of crime scene reconstruction. (© Richard C. Li.)

If the results of the experiment are consistent with the hypothesis, a theory can be developed that is intended to provide valuable information to the investigation and future prosecution of a case. Sometimes, forensic scientists may find that the hypothesis is inconsistent with the test results. In that case, an alternative hypothesis needs to be constructed to initiate another reconstruction process. Figure 1.45 illustrates the scientific process of crime scene reconstruction.

Bibliography

Ackermann, K., K.N. Ballantyne, and M. Kayser, Estimating trace deposition time with circadian biomarkers: A prospective and versatile tool for crime scene reconstruction. *Int J Legal Med*, 2010, **124**(5): 387–395.

Adderley, R. and J.W. Bond, The effects of deprivation on the time spent examining crime scenes and the recovery of DNA and fingerprints. *J Forensic Sci*, 2008, **53**(1): 178–182.

Barash, M., A. Reshef, and P. Brauner, The use of adhesive tape for recovery of DNA from crime scene items. *J Forensic Sci*, 2010, **55**(4): 1058–1064.

Benschop, C.C., et al., Post-coital vaginal sampling with nylon flocked swabs improves DNA typing. *Forensic Sci Int Genet*, 2010, **4**(2): 115–121.

Bond, J.W. and C. Hammond, The value of DNA material recovered from crime scenes. *J Forensic Sci*, 2008, **53**(4): 797–801.

Brownlow, R.J., K.E. Dagnall, and C.E. Ames, A comparison of DNA collection and retrieval from two swab types (cotton and nylon flocked swab) when processed using three QIAGEN extraction methods. *J Forensic Sci*, 2012, **57**(3): 713–717.

Buck, U., et al., Accident or homicide—Virtual crime scene reconstruction using 3D methods. *Forensic Sci Int*, 2013, **225**(1–3): 75–84.

Byard, R.W., et al., "Murder-suicide" or "murder-accident"? Difficulties with the analysis of cases. *J Forensic Sci*, 2010, **55**(5): 1375–1377.

Castello, A., F. Frances, and F. Verdu, Solving underwater crimes: Development of latent prints made on submerged objects. *Sci Justice*, 2013, **53**(3): 328–331.

Chen, T., et al., A rapid wire-based sampling method for DNA profiling. *J Forensic Sci*, 2012, **57**(2): 472–477.
Clarke, M., Alleged rape: An appeal case. *J Forensic Leg Med*, 2008, **15**(1): 32–36.
Courts, C., B. Madea, and C. Schyma, Persistence of biological traces in gun barrels—An approach to an experimental model. *Int J Legal Med*, 2011, **126**(3): 391–397.
Crispino, F., Nature and place of crime scene management within forensic sciences. *Sci Justice*, 2008, **48**(1): 24–28.
Durnal, E.W., Crime scene investigation (as seen on TV). *Forensic Sci Int*, 2010, **199**(1–3): 1–5.
Edelman, G., I. Alberink, and B. Hoogeboom, Comparison of the performance of two methods for height estimation. *J Forensic Sci*, 2010, **55**(2): 358–365.
Eldredge, K., E. Huggins, and L.C. Pugh, Alternate light sources in sexual assault examinations: An evidence-based practice project. *J Forensic Nurs*, 2012, **8**(1): 39–44.
Fisher, B., *Techniques of Crime Scene Investigation*, 7th edn., 2004. Boca Raton, FL: CRC Press.
Gokdogan, M.R. and J. Bafra, Development of a sexual assault evidence collection kit—The need for standardization in Turkey. *Nurse Educ Today*, 2010, **30**(4): 285–290.
Gosnell, J., Case three: Collection of evidence in a murder investigation. *Clin Lab Sci*, 2008, **21**(2): 124–125.
Gunasekera, R.S., A.B. Brown, and E.H. Costas, Tales from the grave: Opposing autopsy reports from a body exhumed. *J Forensic Leg Med*, 2012, **19**(5): 297–301.
Hammer, U. and A. Buttner, Distinction between forensic evidence and post-mortem changes of the skin. *Forensic Sci Med Pathol*, 2012, **8**(3): 330–333.
Hollmann, T., R.W. Byard, and M. Tsokos, The processing of skeletonized human remains found in Berlin, Germany. *J Forensic Leg Med*, 2008, **15**(7): 420–425.
Hornor, G., et al., Pediatric sexual assault nurse examiner care: Trace forensic evidence, ano-genital injury, and judicial outcomes. *J Forensic Nurs*, 2012, **8**(3): 105–111.
Hulse-Smith, L. and M. Illes, A blind trial evaluation of a crime scene methodology for deducing impact velocity and droplet size from circular bloodstains. *J Forensic Sci*, 2007, **52**(1): 65–69.
Ingemann-Hansen, O. and A.V. Charles, Forensic medical examination of adolescent and adult victims of sexual violence. *Best Pract Res Clin Obstet Gynaecol*, 2013, **27**(1): 91–102.
Ingemann-Hansen, O., et al., Legal aspects of sexual violence—Does forensic evidence make a difference? *Forensic Sci Int*, 2008, **180**(2–3): 98–104.
Jina, R., et al., Recovering of DNA evidence after rape. *S Afr Med J*, 2011, **101**(10): 758–759.
Kaliszan, M., et al., Striated abrasions from a knife with non-serrated blade—Identification of the instrument of crime on the basis of an experiment with material evidence. *Int J Legal Med*, 2011, **125**(5): 745–748.
Komar, D.A., S. Lathrop, and S. American, The use of material culture to establish the ethnic identity of victims in genocide investigations: A validation study from the American Southwest. *J Forensic Sci*, 2008, **53**(5): 1035–1039.
Larkin, B.A.J., et al., Crime scene investigation III: Exploring the effects of drugs of abuse and neurotransmitters on bloodstain pattern analysis. *Anal Methods*, 2012, **4**(3): 721–729.
Lee, H.C. and C. Ladd, Preservation and collection of biological evidence. *Croat Med J*, 2001, **42**(3): 225–228.
Lee, H.C. and E.M. Pagliaro, Forensic evidence and crime scene investigation. *J Forensic Invest*, 2013, **1**(1): 1–5.
Lee, H.C., T. Palmbach, and M.T. Miller, *Henry Lee's Crime Scene Handbook*, 2001. San Diego: Academic Press.
Lee, H.C., et al., Guidelines for the collection and preservation of DNA evidence. *J Forensic Ident*, 1991, **41**(5): 13.
Ma, M., H. Zheng, and H. Lallie, Virtual reality and 3D animation in forensic visualization. *J Forensic Sci*, 2010, **55**(5): 1227–1231.
Marchant, B. and C. Tague, Developing fingerprints in blood: A comparison of several chemical techniques. *J Forensic Ident*, 2007, **57**(1): 76–93.
Matte, M., et al., Prevalence and persistence of foreign DNA beneath fingernails. *Forensic Sci Int Genet*, 2012, **6**(2): 236–243.
Mennell, J., The future of forensic and crime scene science. Part II. A UK perspective on forensic science education. *Forensic Sci Int*, 2006, **157**(Suppl 1): S13–S20.
Morgan, J.A., Comparison of cervical os versus vaginal evidentiary findings during sexual assault exam. *J Emerg Nurs*, 2008, **34**(2): 102–105.
Mulligan, C.M., S.R. Kaufman, and L. Quarino, The utility of polyester and cotton as swabbing substrates for the removal of cellular material from surfaces. *J Forensic Sci*, 2011, **56**(2): 485–490.
National Institute of Justice. Using DNA to solve cold cases, Special Report, 2002. Washington, DC: US Department of Justice, Office of Justice Programs, Washington, DC, 2002.
Newton, M., The forensic aspects of sexual violence. *Best Pract Res Clin Obstet Gynaecol*, 2013, **27**(1): 77–90.

Nikolic, S. and V. Zivkovic, A healed bony puzzle: An old gunshot wound to the head. *Forensic Sci Med Pathol*, 2013, **9**(1): 112–116.

Nunn, S., Touch DNA collection versus firearm fingerprinting: Comparing evidence production and identification outcomes. *J Forensic Sci*, 2013, **58**(3): 601–608.

Oliva, A., et al., State of the art in forensic investigation of sudden cardiac death. *Am J Forensic Med Pathol*, 2011, **32**(1): 1–16.

Oliver, W.R. and L. Leone, Digital UV/IR photography for tattoo evaluation in mummified remains. *J Forensic Sci*, 2012, **57**(4): 1134–1136.

Osterkamp, T., K9 water searches: Scent and scent transport considerations. *J Forensic Sci*, 2011, **56**(4): 907–912.

Porta, D., et al., The importance of an anthropological scene of crime investigation in the case of burnt remains in vehicles: 3 case studies. *Am J Forensic Med Pathol*, 2013, **34**(3): 195–200.

Pringle, J.K., J.P. Cassella, and J.R. Jervis, Preliminary soilwater conductivity analysis to date clandestine burials of homicide victims. *Forensic Sci Int*, 2010, **198**(1–3): 126–133.

Ribaux, O., et al., Intelligence-led crime scene processing. Part I: Forensic intelligence. *Forensic Sci Int*, 2010, **195**(1–3): 10–16.

Ribaux, O., et al., Intelligence-led crime scene processing. Part II: Intelligence and crime scene examination. *Forensic Sci Int*, 2010, **199**(1–3): 63–71.

Rios, L., J.I. Ovejero, and J.P. Prieto, Identification process in mass graves from the Spanish Civil War I. *Forensic Sci Int*, 2010, **199**(1–3): e27–e36.

Rutty, G.N., A. Hopwood, and V. Tucker, The effectiveness of protective clothing in the reduction of potential DNA contamination of the scene of crime. *Int J Legal Med*, 2003, **117**(3): 170–174.

Sakelliadis, E.I., C.A. Spiliopoulou, and S.A. Papadodima, Forensic investigation of child victim with sexual abuse. *Indian Pediatr*, 2009, **46**(2): 144–151.

Sansoni, G., et al., Scene-of-crime analysis by a 3-dimensional optical digitizer: A useful perspective for forensic science. *Am J Forensic Med Pathol*, 2011, **32**(3): 280–286.

Schmidt, A., Crime scene investigation approach to sudden cardiac death. *J Am Coll Cardiol*, 2013, **62**(7): 630–631.

Schyma, C., B. Madea, and C. Courts, Persistence of biological traces in gun barrels after fatal contact shots. *Forensic Sci Int Genet*, 2013, **7**(1): 22–27.

Sharma, L., V.P. Khanagwal, and P.K. Paliwal, Homicidal hanging. *Legal Med*, 2011, **13**(5): 259–261.

Shaw, J. and R. Campbell, Predicting sexual assault kit submission among adolescent rape cases treated in forensic nurse examiner programs. *J Interpers Violence*, 2013, **28**(18): 3400–3417.

Shuttlewood, A.C., J.W. Bond, and L.L. Smith, The relationship between deprivation and forensic material recovered from stolen vehicles: Is it affected by vehicle condition and tidiness? *J Forensic Sci*, 2011, **56**(2): 510–513.

Smith, P.A., et al., Measuring team skills in crime scene investigation: Exploring ad hoc teams. *Ergonomics*, 2008, **51**(10): 1463–1488.

Solla, M., et al., Experimental forensic scenes for the characterization of ground-penetrating radar wave response. *Forensic Sci Int*, 2012, **220**(1–3): 50–58.

Taroni, F., et al., Whose DNA is this? How relevant a question? (a note for forensic scientists). *Forensic Sci Int Genet*, 2013, **7**(4): 467–470.

Thackeray, J.D., et al., Forensic evidence collection and DNA identification in acute child sexual assault. *Pediatrics*, 2011, **128**(2): 227–232.

Trombka, J.I., et al., Crime scene investigations using portable, non-destructive space exploration technology. *Forensic Sci Int*, 2002, **129**(1): 1–9.

Uzun, I., et al., Identification procedures as a part of death investigation in Turkey. *Am J Forensic Med Pathol*, 2012, **33**(1): 1–3.

Verdon, T.J., R.J. Mitchell, and R.A. van Oorschot, Swabs as DNA collection devices for sampling different biological materials from different substrates. *J Forensic Sci*, 2014, **59**(4): 1080–1089.

Wahlsten, P., V. Koiranen, and P. Saukko, Survey of medico-legal investigation of homicides in the city of Turku, Finland. *J Forensic Leg Med*, 2007, **14**(5): 243–252.

Walter, B.S. and J.J. Schultz, Mapping simulated scenes with skeletal remains using differential GPS in open environments: An assessment of accuracy and practicality. *Forensic Sci Int*, 2013, **228**(1–3): e33–e46.

Westen, A.A., R.R. Gerretsen, and G.J. Maat, Femur, rib, and tooth sample collection for DNA analysis in disaster victim identification (DVI): A method to minimize contamination risk. *Forensic Sci Med Pathol*, 2008, **4**(1): 15–21.

Wiegand, P., et al., Transfer of biological stains from different surfaces. *Int J Legal Med*, 2011, **125**(5): 727–731.