



Criminalistics

An Introduction to Forensic Science

Thirteenth Edition

CRIME SCENE DO NOT

Richard Saferstein
Tiffany Roy



Edition

13

Criminalistics

An Introduction to Forensic Science

Richard Saferstein, Ph.D.

Forensic Science Consultant, Mt. Laurel, New Jersey

Tiffany Roy



Please contact <https://support.pearson.com/getsupport/s/contactsupport> with any queries on this content

Cover Image by Sergei Drozd/Shutterstock; Microgen/Shutterstock; Johan Swanepoel/Shutterstock; igorstevanovic/Shutterstock

Microsoft and/or its respective suppliers make no representations about the suitability of the information contained in the documents and related graphics published as part of the services for any purpose. All such documents and related graphics are provided “as is” without warranty of any kind. Microsoft and/or its respective suppliers hereby disclaim all warranties and conditions with regard to this information, including all warranties and conditions of merchantability, whether express, implied or statutory, fitness for a particular purpose, title and non-infringement. In no event shall Microsoft and/or its respective suppliers be liable for any special, indirect or consequential damages or any damages whatsoever resulting from loss of use, data or profits, whether in an action of contract, negligence or other tortious action, arising out of or in connection with the use or performance of information available from the services.

The documents and related graphics contained herein could include technical inaccuracies or typographical errors. Changes are periodically added to the information herein. Microsoft and/or its respective suppliers may make improvements and/or changes in the product(s) and/or the program(s) described herein at any time. Partial screen shots may be viewed in full within the software version specified.

Microsoft® and Windows® are registered trademarks of the Microsoft Corporation in the U.S.A. and other countries. This book is not sponsored or endorsed by or affiliated with the Microsoft Corporation.

Copyright © 2021, 2018, 2015 by Pearson Education, Inc. or its affiliates, 221 River Street, Hoboken, NJ 07030. All Rights Reserved. Manufactured in the United States of America. This publication is protected by copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise. For information regarding permissions, request forms, and the appropriate contacts within the Pearson Education Global Rights and Permissions department, please visit www.pearsoned.com/permissions/.

Acknowledgments of third-party content appear on the appropriate page within the text.

PEARSON, ALWAYS LEARNING, REVEL, and MYLAB are exclusive trademarks owned by Pearson Education, Inc. or its affiliates in the U.S. and/or other countries.

Unless otherwise indicated herein, any third-party trademarks, logos, or icons that may appear in this work are the property of their respective owners, and any references to third-party trademarks, logos, icons, or other trade dress are for demonstrative or descriptive purposes only. Such references are not intended to imply any sponsorship, endorsement, authorization, or promotion of Pearson’s products by the owners of such marks, or any relationship between the owner and Pearson Education, Inc., or its affiliates, authors, licensees, or distributors.

Library of Congress Cataloging-in-Publication Data

Names: Saferstein, Richard, author.

Title: Criminalistics : an introduction to forensic science / Richard

Saferstein, Ph.D., Forensic Science Consultant, Mt. Laurel, New Jersey.

Other titles: An introduction to forensic science | Pearson education book.

Description: Thirteenth Edition. | New York : Pearson, 2020. | Includes bibliographical references and index.

Identifiers: LCCN 2019033731 | ISBN 9780135218310 (Paperback) |

ISBN 0135218314 (Paperback) | ISBN 9780135268797 (ePUB)

Subjects: LCSH: Criminal investigation. | Forensic ballistics. | Chemistry, Forensic. | Medical jurisprudence.

Classification: LCC HV8073 .S2 2020 | DDC 363.25—dc23

LC record available at <https://lccn.loc.gov/2019033731>

Revel Access Code

ISBN 10: 0-13-526825-7

ISBN 13: 978-0-13-526825-4

Rental Edition

ISBN 10: 0-13-521831-4

ISBN 13: 978-0-13-521831-0

Instructor’s Review Copy

ISBN 10: 0-13-670658-4

ISBN 13: 978-0-13-670658-8

ScoutAutomatedPrintCode



To the memory of Fran, Michael and Richard

This page is intentionally left blank

Brief Contents



Preface xi

About the Author xviii

■ Chapter 1		■ Chapter 11	
Introduction	1	Hairs and Fibers	249
■ Chapter 2		■ Chapter 12	
The Crime Scene	29	Drugs	281
■ Chapter 3		■ Chapter 13	
Physical Evidence	61	Forensic Toxicology	321
■ Chapter 4		■ Chapter 14	
Crime-Scene Reconstruction: Bloodstain Pattern Analysis	79	Metals, Paint, and Soil	349
■ Chapter 5		■ Chapter 15	
Death Investigation	101	Forensic Serology	375
■ Chapter 6		■ Chapter 16	
Fingerprints	127	DNA: The Indispensable Forensic Science Tool	399
■ Chapter 7		■ Chapter 17	
Forensic Biometrics	151	Forensic Aspects of Fire and Explosion Investigation	431
■ Chapter 8		■ Chapter 18	
The Microscope	167	Document Examination	463
■ Chapter 9		■ Chapter 19	
Firearms, Tool Marks, and Other Impressions	187	Computer Forensics	481
■ Chapter 10		■ Chapter 20	
Matter, Light, and Glass Examination	223	Mobile Device Forensics	509
		Appendixes	525
		Index	537



Contents

Preface xi

About the Author xviii

Chapter 1

Introduction	1
Definition and Scope of Forensic Science	3
History and Development of Forensic Science	5
Crime Laboratories	8
Organization of a Crime Laboratory	9
Case Files	
Forensic Science Helps Unravel the Mystery of the Anthrax Letters	13
Functions of the Forensic Scientist	14
Case Files	
Dr. Coppolino's Deadly House Calls	19
Other Forensic Science Services	22
Chapter Summary	24
Review Questions	25
Application and Critical Thinking	26
Further References	28

Chapter 2

The Crime Scene	29
Processing the Crime Scene	31
Collecting and Packaging Physical Evidence	43
Maintaining the Chain of Custody	47
Ensuring Crime-Scene Safety	48
Legal Considerations at the Crime Scene	50
Chapter Summary	51
Review Questions	52
Application and Critical Thinking	53
Further References	54
Case Analysis	54
Case Study	
The Enrique Camarena Case: A Forensic Nightmare	55

Chapter 3

Physical Evidence	61
Common Types of Physical Evidence	63
The Significance of Physical Evidence	64
Forensic Databases	71
Case Files	
Gerald Wallace	74
Case Files	
The Center City Rapist	74
Case Files	
NIBIN Links Handgun to Suspects	75
Case Files	
Aztec Gold Metallic Hit and Run	75
Chapter Summary	76
Review Questions	77
Application and Critical Thinking	77
Further References	78

Chapter 4

Crime-Scene Reconstruction: Bloodstain Pattern Analysis	79
Crime-Scene Reconstruction	81
General Features of Bloodstain Formation	82
Case File	
Pistorius: A Valentine's Day Murder	82
Bloodstain Spatter Patterns	84
Classifying Impact Pattern	85
Origin of Impact Patterns	87
More Bloodstain Spatter Patterns	87
Case Files	
Blood-Spatter Evidence	88
Documenting Bloodstain Pattern Evidence	94

Case Files

Bloodstain Reconstruction	95
Chapter Summary	98
Review Questions	98
Application and Critical Thinking	99
Further References	100

Chapter 5

Death Investigation	101
Role of the Forensic Pathologist	103
The Autopsy	104
Cause of Death	107

Case Files

Harold Shipman, Dr. Death	108
Manner of Death	110

Case Files

The Sheridans: Murder or Suicide	112
Estimating Time of Death	113
Role of the Forensic Anthropologist	115

Case Files

Identifying a Serial Killer's Victims	120
Role of the Forensic Entomologist	121

Case Files

The Danielle Van Dam Murder Case	122
Chapter Summary	123
Review Questions	123
Application and Critical Thinking	125
Further References	126

Chapter 6

Fingerprints	127
History of Fingerprinting	129
Fundamental Principles of Fingerprints	130
Classification of Fingerprints	135
Automated Fingerprint Identification Systems	136
Methods of Detecting Fingerprints	138

Case Files

The Night Stalker	138
--------------------------	------------

Case Files

The Mayfield Affair	139
Preservation of Developed Prints	145

Digital Imaging for Fingerprint Enhancement	145
Chapter Summary	147
Review Questions	148
Application and Critical Thinking	149
Further References	150

Chapter 7

Forensic Biometrics	151
Introduction to Biometrics	153
Enrolling and Extracting Biometric Data	155
The Iris	156
Facial Recognition	159

Case Files

Living a Double Life	162
The Next-Generation Identification System	162
Chapter Summary	165
Review Questions	165
Application and Critical Thinking	166
Further References	166

Chapter 8

The Microscope	167
Basics of the Microscope	169
The Compound Microscope	170
The Comparison Microscope	172
The Stereoscopic Microscope	174
The Polarizing Microscope	175
The Microspectrophotometer	176
The Scanning Electron Microscope	177
Forensic Palynology: Pollen and Spores as Evidence	179

Case Files

Identifying Baby Doe	182
-----------------------------	------------

Case Files

Clues from the Cornfield	183
Chapter Summary	184
Review Questions	184
Application and Critical Thinking	185
Further References	185

Chapter 9

Firearms, Tool Marks, and Other Impressions 187

Types of Firearms	189
Bullet and Cartridge Comparisons	190
Automated Firearms Search Systems	197

Case Files

Sacco and Vanzetti	198
Gunpowder Residues	201
Primer Residues on the Hands	204
Serial Number Restoration	207
Collection and Preservation of Firearms Evidence	208
Tool Marks	209
Other Impressions	212

Case Files

The O. J. Simpson Trial—Who Left the Impressions at the Crime Scene?	219
Chapter Summary	219
Review Questions	220
Application and Critical Thinking	221
Further References	222

Chapter 10

Matter, Light, and Glass Examination 223

The Nature of Matter	225
Physical Properties of Matter	228
Theory of Light	235
Forensic Analysis of Glass	237
Glass Fractures	243
Collection and Preservation of Glass Evidence	245
Chapter Summary	246
Review Questions	246
Review Questions for Inside the Science	247
Application and Critical Thinking	248
Further References	248

Chapter 11

Hairs and Fibers 249

Morphology of Hair	251
Identification and Comparison of Hair	256

Case Files

The Central Park Jogger Case Revisited	257
Collection and Preservation of Hair Evidence	260
Forensic Examination of Fibers	260

Case Files

The Ennis Cosby Homicide	261
Identification and Comparison of Manufactured Fibers	265

Case Files

Jeffrey MacDonald: Fatal Vision	269
Collection and Preservation of Fiber Evidence	271

Case Files

Fiber Evidence and the Wayne Williams Trial	272
Chapter Summary	275
Review Questions	276
Review Questions for Inside the Science	277
Application and Critical Thinking	277
Further References	279

Chapter 12

Drugs 281

Drug Dependence	283
Types of Drugs	285
Drug-Control Laws	297
Collection and Preservation of Drug Evidence	299
Forensic Drug Analysis	299
Chromatography	302
Spectrophotometry	310
Mass Spectrometry	313
Chapter Summary	316
Review Questions	317
Review Questions for Inside the Science	319
Application and Critical Thinking	319
Further References	320

Chapter 13

Forensic Toxicology 321

Toxicology of Alcohol	323
Testing for Intoxication	327
Field Sobriety Testing	330
Analysis of Blood for Alcohol	332

Alcohol and the Law	333
The Role of the Toxicologist	336

Case Files

Michael Jackson: The Demise of a Superstar	337
--------------------------------------------	-----

Case Files

Accidental Overdose: The Tragedy of Anna Nicole Smith	338
----------------------------------------------------------	-----

Case Files

Joann Curley: Caught by a Hair	342
The Drug Recognition Expert	343
Chapter Summary	345
Review Questions	346
Review Questions for Inside the Science	347
Application and Critical Thinking	347
Further References	348

Chapter 14

Metals, Paint, and Soil	349
Forensic Analysis of Trace Elements	350
Principles and Technology of Trace Analysis	354

Case Files

Death by Radiation Poisoning	360
Forensic Examination of Paint	363

Case Files

The Predator	368
Forensic Analysis of Soil	369

Case Files

Soil: The Silent Witness	371
Collection and Preservation of Soil Evidence	372
Chapter Summary	372
Review Questions	373
Review Questions for Inside the Science	374
Application and Critical Thinking	374
Further References	374

Chapter 15

Forensic Serology	375
The Nature of Blood	377
Blood Typing	379
Immunoassay Techniques	381

Forensic Characterization of Bloodstains	381
Principles of Heredity	387
Forensic Characterization of Semen	389
Collection and Preservation of Rape Evidence	392

Case Files

A DNA Bonus	395
Chapter Summary	396
Review Questions	397
Review Questions for Inside the Science	398
Application and Critical Thinking	398
Further References	398

Chapter 16

DNA: The Indispensable Forensic Science Tool	399
What Is DNA?	401
DNA at Work	403
Replication of DNA	404
DNA Typing with Short Tandem Repeats	405

Case Files

Reopening the Boston Strangler Case	414
Mitochondrial DNA	415

Case Files

Cold Case Hit	416
Collection and Preservation of Biological Evidence for DNA Analysis	418

Case Files

Contact Lens Evidence	422
-----------------------	-----

Case Files

The JonBenét Ramsey Murder Case	422
Chapter Summary	425
Review Questions	426
Review Questions for Inside the Science	427
Application and Critical Thinking	427
Further References	429

Chapter 17

Forensic Aspects of Fire and Explosion Investigation	431
The Chemistry of Fire	433

Heat Transfer	438
Conduction	438
Radiation	439
Convection	439
Searching the Fire Scene	440

Case Files

The Sackett Street Fire	442
Collection and Preservation of Arson Evidence	443
Analysis of Flammable Residues	444
Explosions and Explosives	447
Types of Explosives	449
Collection and Analysis of Evidence of Explosives	453

Case Files

Liquid Explosives	454
Chapter Summary	458
Review Questions	459
Review Questions for Inside the Science	460
Application and Critical Thinking	460
Further References	462

Chapter 18

Document Examination	463
Document Examiner	465
Handwriting Comparisons	465
Collection of Handwriting Exemplars	468
Typescript Comparisons	470
Alterations, Erasures, and Obliterations	472
Other Document Problems	474
Chapter Summary	479
Review Questions	480
Application and Critical Thinking	480
Further References	480

Chapter 19

Computer Forensics	481
From Input to Output: How Does the Computer Work?	483
Storing and Retrieving Data	488
Processing the Electronic Crime Scene	489
Analysis of Electronic Data	492
Forensic Analysis of Internet Data	498

Forensic Investigation of Internet Communications	500
Hacking	503
Mobile Forensics	504
Chapter Summary	506
Review Questions	506
Application and Critical Thinking	507
Further References	508

Chapter 20

Mobile Device Forensics	509
The Mobile Device Neighborhood: What Makes a Mobile Device “Mobile”?	511
Forensic Challenges: Mobile Devices as Small Computers—Sort Of	512
Extracting Useful Data: The Differences in Various Types of Mobile Devices	514
Mobile Device Architecture: What Is Inside the Device and What Is It Used For?	516
Analyzing Mobile Devices: Finding Forensically Valuable Artifacts	517

Case File

The FBI v. Apple: The Encryption Dispute	518
Hybrid Crime Assessment: Fitting the Mobile Device into the Digital Forensic Investigation	520

Case File

Carpenter v. United States	522
Chapter Summary	523
Review Questions	523
Application and Critical Thinking	524
Further References	524

Appendixes 525

I Code of Professional Responsibility for the Practice of Forensic Science	526
II Handbook of Forensic Services—FBI	527
III Instructions for Collecting Gunshot Residue (GSR)	528
IV Chemical Formulas for Latent Fingerprint Development	530
V Chemical Formulas for Development of Footwear Impressions in Blood	534

Index 537



Public Fascination with Forensic Science

Many readers of this book have been drawn to the subject of forensic science by the assortment of television shows about scientific crime investigation. Story lines depicting the crime-solving abilities of forensic scientists have greatly excited the imagination of the general public. Furthermore, a constant of forensic science is how frequently its applications become front-page news. Whether the story is the sudden death of pop music superstar Michael Jackson, sniper shootings, or the tragic consequences of the terrorist attacks of 9/11, forensic science is at the forefront of the public response.

During the highly publicized O. J. Simpson criminal and civil trials, forensic scientists systematically placed Simpson at the crime scene through DNA analyses, hair and fiber comparisons, and footwear impressions. As millions of Americans watched the case unfold, they, in a sense, became students of forensic science. Intense media coverage of the crime-scene search and investigation, as well as the ramifications of findings of physical evidence at the crime scene, became the subject of study, commentary, and conjecture.

For instructors who have taught forensic science in the classroom, it comes as no surprise that forensic science can grab and hold the attention of those who otherwise would have no interest in any area of science. The O. J. Simpson case, for example, amply demonstrates the extent to which forensic science has intertwined with criminal investigation.

Perhaps we can attribute our obsession with forensic science to the yearnings of a society bent on apprehending criminals but desirous of a system of justice that ensures the correctness of its verdicts. The level of sophistication that forensic science has brought to criminal investigations is formidable. But once one puts aside all the drama of a forensic science case, what remains is *an academic subject emphasizing logic and technology*.

Purpose of This Book

It is to this end—revealing that essence of forensic science—that the thirteenth edition of *Criminalistics* is dedicated. The basic aim of the book is still to make the subject of forensic science clear and comprehensible to a wide variety of readers who are or plan to be aligned with the forensic science profession, as well as to those who have a curiosity about the subject's underpinnings.

DNA profiling has altered the complexion of criminal investigation. DNA collected from saliva on a cup or from dandruff or sweat on a hat exemplifies the emergence of nontraditional forms of evidence collection at crime scenes. Currently, the criminal justice system is creating vast DNA data banks designed to snare criminals who are unaware of the consequences of leaving the minutest quantity of biological material behind at a crime scene.

New to This Edition

- Numerous case files have been added to select chapters to illustrate how forensic technology has been applied to solving crimes of notoriety.
- Chapter 4 “Crime scene Reconstruction: Bloodstain Pattern Analysis” has been updated to reflect changes in terminology and interpretation of blood stain pattern evidence.
- Chapter 16, “DNA: The Indispensable Forensic Science Tool,” has been updated to including information on the use of Rapid DNA systems, Probabilistic Genotyping and Forensic Genetic Genealogy.
- Chapter 1, “Introduction,” has been expanded to cover the discussion of the reliability and controversy surrounding forensic bite mark comparison.

- Chapter 20, “Mobile Device Forensics,” has been updated to discuss the impact of *Carpenter v. United States* and an overview of the use of a StingRay device.
- Information throughout the text has been updated and many new figures have been added to illustrate concepts discussed in the chapters.

Focus on Cutting-Edge Tools and Techniques

Through thirteen editions, *Criminalistics* has strived to depict the role of the forensic scientist in the criminal justice system. The current edition builds on the content of its predecessors and updates the reader on the latest technologies available to crime laboratory personnel.

A new chapter has been added to this edition dealing with the subject of forensic biometrics. The reader is introduced to the FBI’s recently implemented Next Generation Identification System which houses its fingerprint and facial recognition databases.

The computer, the Internet, and mobile electronic devices have influenced all aspects of modern life, and forensic science is no exception. Chapter 19, “Computer Forensics,” and Chapter 20, “Mobile Devices Forensics,” explore the retrieval of computerized information thought to be lost or erased during the course of a criminal investigation and delve into the investigation of hacking incidents.

A major portion of the text centers on discussions of the common items of physical evidence encountered at crime scenes. Various chapters include descriptions of forensic analysis, as well as updated techniques for the proper collection and preservation of evidence at crime scenes. The reader is offered the option of delving into the more difficult technical aspects of the subject by reading the “Inside the Science” features. This option can be bypassed without detracting from a basic comprehension of the subject of forensic science.

The implications of DNA profiling are important enough to warrant their inclusion in a separate chapter in *Criminalistics*. Chapter 16 describes the topic of DNA in a manner that is comprehensible and relevant to readers who lack a scientific background. The discussion defines DNA and explains its central role in controlling the body’s chemistry. Finally, Chapter 16 explains the process of DNA typing and illustrates its application to criminal investigations through the presentation of actual case histories.

A Grounded Approach

The content of *Criminalistics* reflects the author’s experience as both an active forensic scientist and an instructor of forensic science at the college level. The author assumes that readers have no prior knowledge of scientific principles or techniques. The areas of chemistry and biology relating to the analysis of physical evidence are presented with a minimum of scientific terminology and equations. The discussion involving chemistry and biology is limited to a minimum core of facts and principles that make the subject matter understandable and meaningful to the nonscientist. Although it is not the intent of this book to turn readers into scientists or forensic experts, the author would certainly be gratified if the book motivates some students to seek further scientific knowledge and perhaps direct their education toward careers in forensic science.

Although *Criminalistics* is an outgrowth of a one-semester course offered as part of a criminal justice program at many New Jersey colleges, the value of the book is not limited to college students. Optimum utilization of crime laboratory services requires that criminal investigators have knowledge of the techniques and capabilities of the laboratory. That awareness extends beyond any summary that may be gleaned from departmental brochures dealing with the collection and packaging of physical evidence. Investigators must mesh knowledge of the principles and techniques of forensic science with logic and common sense to gain comprehensive insight into the meaning and significance of physical evidence and its role in

criminal investigations. Forensic science begins at the crime scene. If the investigator cannot recognize, collect, and package evidence properly, no amount of equipment or expertise will salvage the situation.

Likewise, there is a dire need to bridge the “communication gap” that currently exists among lawyers, judges, and forensic scientists. An intelligent evaluation of the scientist’s data and any subsequent testimony will again depend on familiarity with the underlying principles of forensic science. Too many practitioners of the law profess ignorance of the subject or attempt to gain a superficial understanding of its meaning and significance only minutes before meeting the expert witness. It is hoped that the book will provide a painless route to comprehending the nature of the science.

In order to merge theory with practice, actual forensic case histories are included in the text. The intent is for these illustrations to move forensic science from the domain of the abstract into the real world of criminal investigation.

Key Features of the Thirteenth Edition

The Thirteenth edition, which is now available in a variety of print and electronic formats, presents modern forensic science approaches and techniques with the aid of real-life examples, up-to-date information, and interactive media. Key features include the following:

Headline News stories at the beginning of each chapter introduce readers to the chapter topics by describing high-profile crimes and the related forensic science techniques used in the investigations.

RSS

Headline News

Steven Avery: Making a Murderer




The case of Steven Avery captured America’s attention when it was featured in the Netflix documentary *Making a Murderer*. The documentary detailed the case of Avery, who was wrongfully convicted in 1985 of sexual assault and attempted murder. After serving 18 years of a 20-year sentence, he was exonerated by DNA testing and released.

In 2003, Avery filed a \$36 million lawsuit against Manitowoc County, its former sheriff, and its former district attorney for wrongful conviction and imprisonment. In November 2005, with his civil suit still pending, he was arrested for the murder of Wisconsin photographer Teresa Halbach.

Teresa Halbach was last seen on October 31, 2005. Her last known appointment was a meeting with Avery, at his home on the grounds of Avery’s Auto Salvage, to photograph his sister’s minivan that he was offering for sale on Autotrader.com. During the investigation into her disappearance, Halbach’s vehicle was found partially concealed in the salvage yard, and bloodstains recovered from its interior matched Avery’s DNA. Investigators later identified charred bone fragments found in a burn pit near Avery’s home as Halbach’s. Manitowoc deputy found the key to Halbach’s vehicle in Avery’s bedroom. Avery’s attorneys said there was a conflict of interest in their participation and suggested evidence tampering.

Avery was arrested and charged with Halbach’s murder, kidnapping, sexual assault, and mutilation of a corpse on November 11, 2005. Although Manitowoc County ceded control of the murder investigation to the neighboring Calumet County Sheriff’s Department because of Avery’s suit against Manitowoc County, Manitowoc sheriff’s deputies participated in repeated searches of Avery’s trailer, garage, and property, supervised by Calumet County officers. The case serves as a prime example of the kinds of legal questions that can be raised if proper consideration isn’t given to crime scene search and recovery procedures.

Inside the Science boxes throughout the text explore scientific phenomena and technology in relation to select chapter topics, and are accompanied by Review Questions for Inside the Science at the end of the chapter.

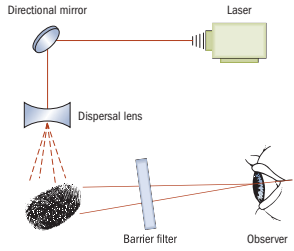


inside the science

Fluorescence

The first hint of things to come was the discovery that latent fingerprints could be visualized by exposure to laser light. This laser method took advantage of the fact that perspiration contains a variety of components that **fluoresce** when illuminated by laser light. Fluorescence occurs when a substance absorbs light and reemits the light in wavelengths longer than the illuminating source. Importantly, substances that emit light or fluoresce are more readily seen with either the naked eye or through photography than are non-light-emitting materials. The high sensitivity of fluorescence serves as the underlying principle of many of the new chemical techniques used to visualize latent fingerprints.

The earliest use of fluorescence to visualize fingerprints came with the direct illumination of a fingerprint with argon-ion lasers. This laser type was chosen because its blue-green light output induced some of the perspiration components of a fingerprint to fluoresce (see figure). The major drawback of this approach is that the perspiration components of a fingerprint are often present in quantities too minute to observe even with the aid of fluorescence. The fingerprint examiner, wearing safety goggles containing optical filters, visually examines the specimen being exposed to the laser light. The filters absorb the laser light and permit the wavelengths at which latent-print residues fluoresce to pass through to the eyes of the



Schematic depicting latent-print detection with the aid of a laser. A fingerprint examiner, wearing safety goggles containing optical filters, examines the specimen being exposed to the laser light. The filter absorbs the laser light and permits the wavelengths at which latent-print residues fluoresce to pass through to the eyes of the

wearer. The filter also protects the operator against eye damage from scattered or reflected laser light. Likewise, latent-print residue producing sufficient fluorescence can be photographed by placing this same filter across the lens of the camera. Examination of specimens and photography of the fluorescing latent prints are carried out in a darkened room.

Case File boxes throughout the text present brief, real-life case examples that are illustrative of the forensic science topics and techniques described in the chapters.

case files


The Night Stalker

Richard Ramirez committed his first murder in June 1984. His victim was a 79-year-old woman who was stabbed repeatedly and sexually assaulted and then had her throat slashed. It would be eight months before Ramirez murdered again. In the spring, Ramirez began a murderous rampage that resulted in 13 additional killings and 5 rapes.

His modus operandi was to enter a home through an open window, shoot the male residents, and savagely rape his female victims. He scribed a pentagram on the wall of one of his victims and the words *Jack the Knife*, and was reported by another to force her to "swear to Satan" during the assault. His identity still unknown, the news media dubbed him the "Night Stalker." As the body count continued to rise, public hysteria and a media frenzy prevailed.

The break in the case came when the license plate of what seemed to be a suspicious car related to a sighting of the Night Stalker was reported to the police. The police determined that the car had been stolen and eventually located it, abandoned in a parking lot. After processing the car for prints, police found one usable partial fingerprint. This fingerprint was entered into the Los Angeles Police Department's brand-new AFIS computerized fingerprint system.

The Night Stalker was identified as Richard Ramirez, who had been fingerprinted following a traffic violation some years before. Police searching the home of one of his friends found the gun used to commit the murders, and jewelry belonging to



Richard Ramirez, the Night Stalker.

Richard Ramirez/Getty Images

his victims was found in the possession of Ramirez's sister. Ramirez was convicted of murder and sentenced to death in 1989, where he died from natural causes in 2013.

Application and Critical Thinking questions at the end of each chapter challenge students to demonstrate their understanding of the material through a variety of question types, including hypothetical scenarios and sets of images for visual identification and analysis. Answers to these questions are provided in the Instructor's Manual.

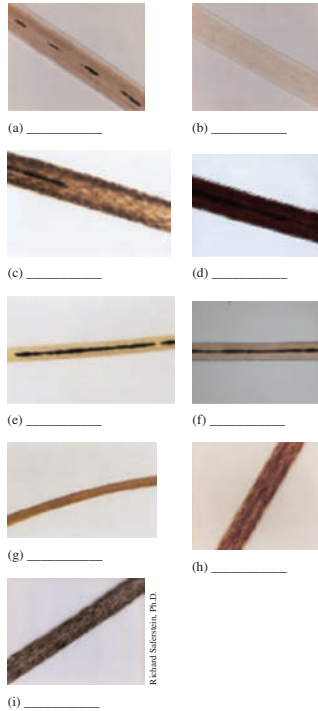
Webextras serve to expand the coverage of the book through video presentations, Internet-related information, animations, and graphic displays keyed to enhancing reader's understanding of the subject's more difficult concepts. Webextras are accessible on the book website at www.pearsonhighered.com/careersresources.

application and critical thinking



1. Indicate the phase of growth of each of the following hairs:
 - a. The root is club-shaped
 - b. The hair has a follicular tag
 - c. The root bulb is flame-shaped
 - d. The root is elongated
2. A criminalist studying a dyed sample hair notices that the dyed color ends about 1.5 centimeters from the tip of the hair. Approximately how many weeks before the examination was the hair dyed? Explain your answer.
3. Following are descriptions of several hairs; based on these descriptions, indicate the likely race of the person from whom the hair originated:
 - a. Evenly distributed, fine pigmentation
 - b. Continuous medullation
 - c. Dense, uneven pigmentation
 - d. Wavy with a round cross-section
4. Criminalist Pete Evett is collecting fiber evidence from a murder scene. He notices fibers on the victim's shirt and trousers, so he places both of these items of clothing in a plastic bag. He also sees fibers on a sheet near the victim, so he balls up the sheet and places it in a separate plastic bag. Noticing fibers adhering to the windowsill from which the attacker gained entrance, Pete carefully removes them with his fingers and places them in a regular envelope. What mistakes, if any, did Pete make while collecting this evidence?

5. For each of the following human hair samples, indicate the medulla pattern present.



Instructor Supplements

Instructor's Manual with Test Bank. Includes content outlines for classroom discussion, teaching suggestions, and answers to selected end-of-chapter questions from the text. This also contains a Word document version of the test bank.

TestGen. This computerized test generation system gives you maximum flexibility in creating and administering tests on paper, electronically, or online. It provides state-of-the-art features for viewing and editing test bank questions, dragging a selected question into a test you are creating, and printing sleek, formatted tests in a variety of layouts. Select test items from test banks included with TestGen for quick test creation, or write your own questions from scratch. TestGen's random generator provides the option to display different text or calculated number values each time questions are used.

PowerPoint Presentations. Our presentations are clear and straightforward. Photos, illustrations, charts, and tables from the book are included in the presentations when applicable.

To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonhighered.com/irc, where you can register for an instructor access code. Within 48 hours after registering, you will receive a confirming email, including an instructor access code. Once you have received your code, go to the site and log on for full instructions on downloading the materials you wish to use.

Alternate Versions

eBooks. This text is also available in multiple eBook formats. These are an exciting new choice for students looking to save money. As an alternative to purchasing the printed textbook, students can purchase an electronic version of the same content. With an eTextbook, students can search the text, make notes online, print out reading assignments that incorporate lecture notes, and bookmark important passages for later review. For more information, visit your favorite online eBook reseller or visit www.mypearsonstore.com.

Revel *Criminalistics*, Thirteenth Edition by Richard Saferstein and Tiffany Roy

Designed for how you want to teach – and how your students want to learn

Revel is an interactive learning environment that engages students and helps them prepare for your class. Reimagining their content, our authors integrate media and assessment throughout the narrative so students can read, explore, and practice, all at the same time. Thanks to this dynamic reading experience, students come to class prepared to discuss, apply, and learn about criminal justice — from you and from each other.

Revel seamlessly combines the full content of Pearson’s bestselling criminal justice titles with multimedia learning tools. You assign the topics your students cover. Author Explanatory Videos, application exercises, survey questions, and short quizzes engage students and enhance their understanding of core topics as they progress through the content. Through its engaging learning experience, Revel helps students better understand course material while preparing them to meaningfully participate in class.



Author Explanatory Videos

Short 2-3 minute Author Explanatory Videos, embedded in the narrative, provide students with a verbal explanation of an important topic or concept and illuminating the concept with additional examples.

Criminalistics Virtual Laboratory Exercises

The *Criminalistics* virtual laboratory exercises are intended to give the student a first-hand look at the types of tests and examinations performed in the crime lab. Using 360-degree photography, microscope imagery and explanatory videos, these laboratory exercises will bring the content to life and give students an opportunity to experience a day in the life of a forensic scientist.



Point/Counterpoint Videos

Instead of simply reading about criminal justice, students are empowered to think critically about key topics through Point/Counterpoint videos that explore different views on controversial issues such as the effectiveness of the fourth amendment, privacy, search and seizure, Miranda, prisoner rights, death penalty and many other topics.

Student Survey Questions

Student Survey Questions appear within the narrative asking students to respond to questions about controversial topics and important concepts. Students then see their response versus the responses of all other students who have answered the question in the form of a bar chart.

Track time-on-task throughout the course

The Performance Dashboard allows you to see how much time the class or individual students have spent reading a section or doing an assignment, as well as points earned per assignment. This data helps correlate study time with performance and provides a window into where students may be having difficulty with the material.

Learning Management System Integration

Pearson provides Blackboard Learn™, Canvas™, Brightspace by D2L, and Moodle integration, giving institutions, instructors, and students easy access to Revel. Our Revel integration delivers streamlined access to everything your students need for the course in these learning management system (LMS) environments.

The Revel App

The Revel mobile app lets students read, practice, and study—anywhere, anytime, on any device. Content is available both online and offline, and the app syncs work across all registered devices automatically, giving students great flexibility to toggle between phone, tablet, and laptop as they move through their day. The app also lets students set assignment notifications to stay on top of all due dates. Available for download from the App Store or Google Play. Visit www.pearson-highered.com/revel/ to learn more.

Acknowledgments

I would like to express my most sincere thanks to Dr. Richard Saferstein and his family for the opportunity to work on this text. It is an honor and privilege. I will work hard to ensure it is up to the high standard set by Richard in his lifetime.

I am most appreciative of my former students, now forensic science colleagues, who worked closely with me on this project. Thank you to Tatum Price of the Palm Beach Sheriff's Office Crime Lab DNA Unit for her work in the development of the interactive content. Thanks to Taj Laing of the West Palm Beach Police Department CSI Unit and Karlee Jonas for their assistance with case selection and text revision.

I would like to thank the subject matter experts who reviewed this text content and recommended updates, including Dr. Michael McCutcheon of the Londonderry, NH Police Department; James Palma of the Palm Beach County Sheriff's Office Firearms Unit; Melissa O'Meara of Vuyronx Technology/Federal Resources, and Jeremiah Morris of the Johnson County Crime Lab in Mission, Kansas. Additionally, I would like to thank Andrew Donofrio and Dr. Peter Stephenson for their previous contributions to this book on the subject of mobile and digital forensics.

I would like to thank Michael Dosmann and the staff at Arnold Arboretum at Harvard University for their assistance.

Many people provided assistance and advice in the preparation of this book. I would like to acknowledge the contributions of Michael Marciano of Syracuse University; Kristi Barba of the Onondaga County Health Department for comments on the DNA and Toxicology chapters, respectively. A big thanks to Amy Brodeur, Dr. Robin Cotton, Dr. Sean Tallman, Dr. Adam Hall, Dr. Sabra Botch-Jones and Robert Bouchie from Boston University School of Medicine for the use of their laboratory facilities in the development of the Revel product for this text. Thank you to everyone who assisted Richard in making this book a success by providing photos and materials including Robert Thompson, Roger Ely, Jose R. Almirall, Darlene Brezinski, Michael Malone, Robert J. Phillips, David Pauly, Dr. Barbara Needell, Marla Carroll, Robin D. Williams, Peter Diaczuk, Jacqueline A. Joseph, John Lentini and Robert Welsh. I'm appreciative for the contributions, reviews, and comments that Dr. Claus Speth, Dr. Mark Taff, Dr. Elizabeth Laposata, Thomas P. Mauriello, and Michelle D. Miranda.

I'm appreciative of the assistance provided by Dr. Adam Freeman, DDS in the area of forensic odontology for guidance on peer reviewed, published literature in the area of forensic bitemark comparison.

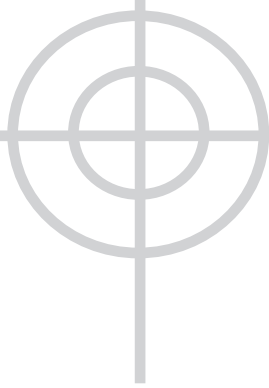
Pearson Education and I would like to thank the reviewers of this edition for their input and guidance:

Gail Anderson, Simon Fraser University; Lisa Dadio, University of New Haven; Barry Michael, University of Memphis; and Charla Perdue, Florida State University - Panama City.

I am grateful to the law enforcement agencies, governmental agencies, private individuals, and equipment manufacturers cited in the text for contributing their photographs and illustrations.

Finally, I would like to thank my family, friends and colleagues for all they have done to support me in my academic and professional pursuits. Any successes I achieve in my lifetime, I owe to the family and friends who love and support me through hard times and celebrate with me in the good.

Tiffany Roy, JD, MSFS



About the Author

Richard Saferstein, Ph.D., retired after serving 21 years as the chief forensic scientist of the New Jersey State Police Laboratory, one of the largest crime laboratories in the United States. He currently acts as a consultant for attorneys and the media in the area of forensic science. During the O. J. Simpson criminal trial, Dr. Saferstein provided extensive commentary on forensic aspects of the case for the *Rivera Live* show, the E! television network, ABC radio, and various radio talk shows. Dr. Saferstein holds degrees from the City College of New York and earned his doctorate degree in chemistry in 1970 from the City University of New York. From 1972 to 1991, he taught an introductory forensic science course in the criminal justice programs at the College of New Jersey and Ocean County College. These teaching experiences played an influential role in Dr. Saferstein's authorship in 1977 of the widely used introductory textbook *Criminalistics: An Introduction to Forensic Science*, currently in this thirteenth edition. Saferstein's basic philosophy in writing *Criminalistics* is to make forensic science understandable and meaningful to the nonscience reader, while giving the reader an appreciation for the scientific principles that underlie the subject.

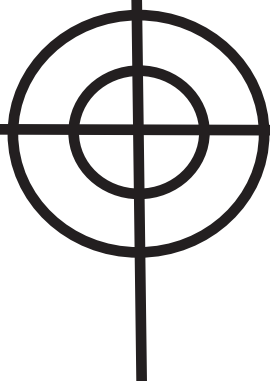
Dr. Saferstein has authored or co-authored more than 45 technical papers and chapters covering a variety of forensic topics. Dr. Saferstein has co-authored *Lab Manual for Criminalistics* (Pearson, 2015) to be used in conjunction with this text. He is also the author of *Forensic Science: An Introduction* (Pearson, 2008 and 2011) and *Forensic Science: From the Crime Scene to the Crime Lab* (2009 and 2015). He has also edited the widely used professional reference books *Forensic Science Handbook*, Volumes I, II, and III, 2nd edition (published in 2002, 2005, and 2010, respectively, by Pearson).

Dr. Saferstein is a member of the American Chemical Society, the American Academy of Forensic Sciences, the Canadian Society of Forensic Scientists, the International Association for Identification, the Northeastern Association of Forensic Scientists, and the Society of Forensic Toxicologists. He is the recipient of the American Academy of Forensic Sciences 2006 Paul L. Kirk Award for distinguished service and contributions to the field of criminalistics.

Tiffany Roy, MSFS, JD is a Forensic DNA expert with over thirteen years of forensic biology experience in both public and private laboratories in the United States. She has processed thousands of DNA samples and thousands of cases over the course of her career. She has provided expert witness testimony in more than one hundred cases in state, federal and international courts. She instructs undergraduates at Palm Beach Atlantic University; University of Maryland Global Campus; and Southern New Hampshire University. She currently acts as a consultant for attorneys and the media in the area of forensic biology through her firm, *ForensicAid, LLC*.

Roy holds degrees from Syracuse University, Massachusetts School of Law and University of Florida in the areas of Biology, Law and Forensic Science. Her teaching, legal writing and testimonial experience help her to take complex scientific concepts and make them easily understandable for the nonscientist. Roy assisted Dr. Saferstein in completing *Forensic Science: From the Crime Scene to the Crime Lab 4e* (Pearson 2019) and has authored the text *The Complete Guide to the American Board of Criminalistics Molecular Biology Examination (CRC Press 2020)* to assist working forensic scientists achieve the goal of certification.

Roy is a member of the American Academy of Forensic Sciences, the Northeastern Association of Forensic Scientists and the Massachusetts Board of Bar Examiners. She is a certified Diplomate in the area of Forensic Biology by the American Board of Criminalistics. Aside from her teaching, writing and consulting, Roy also assists with international capacity building initiatives, providing subject matter expertise for trainings for criminal justice stakeholders in the Middle East and Africa.



Introduction

Learning Objectives

After studying this chapter, you should be able to:

- 1.1 Distinguish between forensic science and criminalistics
- 1.2 Describe the organization and services of a typical comprehensive crime laboratory in the criminal justice system
- 1.3 Explain how physical evidence is analyzed and presented in the courtroom by the forensic scientist, and how admissibility of evidence is determined in the courtroom
- 1.4 Explain the role and responsibilities of the expert witness and what specialized forensic services, aside from the crime laboratory, are generally available to law enforcement personnel

KEY TERMS

expert witness
Locard's exchange
principle
scientific method



Steven Avery: Making a Murderer



GL Archive/Alamy Stock Photo

The case of Steven Avery captured America's attention when it was featured in the Netflix documentary *Making a Murderer*. The documentary detailed the case of Avery, who was wrongfully convicted in 1985 of sexual assault and attempted murder. After serving 18 years of a 20-year sentence, he was exonerated by DNA testing and released.

In 2003, Avery filed a \$36 million lawsuit against Manitowoc County, its former sheriff, and its former district attorney for wrongful conviction and imprisonment. In November 2005, with his civil suit still pending, he was

arrested for the murder of Wisconsin photographer Teresa Halbach.

Teresa Halbach was last seen on October 31, 2005. Her last known appointment was a meeting with Avery, at his home on the grounds of Avery's Auto Salvage, to photograph his sister's minivan that he was offering for sale on Autotrader.com. During the investigation into her disappearance, Halbach's vehicle was found partially concealed in the salvage yard, and bloodstains recovered from its interior matched Avery's DNA. Investigators later identified charred bone fragments found in a burn pit near Avery's home as belonging to Halbach's. A Manitowoc deputy found the key to Halbach's vehicle in Avery's bedroom. Avery's attorneys assert said there was a conflict of interest in the participation of the Manitowoc Sheriff's Department and suggested evidence tampering.

Avery was arrested and charged with Halbach's murder, kidnapping, sexual assault, and mutilation of her corpse on November 11, 2005. Although Manitowoc County ceded control of the murder investigation to the neighboring Calumet County Sheriff's Department because of Avery's law suit, Manitowoc sheriff's deputies participated in repeated searches of Avery's trailer, garage, and property, supervised by Calumet County officers. The case serves as a prime example of the kinds of legal questions that can be raised if proper consideration isn't given to crime scene search and recovery procedures.

Definition and Scope of Forensic Science

Forensic science in its broadest definition is the application of science to law. As our society has grown more complex, it has become more dependent on rules of law to regulate the activities of its members. Forensic science applies the knowledge and technology of science to the definition and enforcement of such laws.

Each year, as government finds it increasingly necessary to regulate the activities that most intimately influence our daily lives, science merges more closely with civil and criminal law. Consider, for example, the laws and agencies that regulate the quality of our food, the nature and potency of drugs, the extent of automobile emissions, the kind of fuel oil we burn, the purity of our drinking water, and the pesticides we use on our crops and plants. It would be difficult to conceive of a food or drug regulation or environmental protection act that could be effectively monitored and enforced without the assistance of scientific technology and the skill of the scientific community.

Laws are continually being broadened and revised to counter the alarming increase in crime rates. In response to public concern, law enforcement agencies have expanded their patrol and investigative functions, hoping to stem the rising tide of crime. At the same time, they are looking more to the scientific community for advice and technical support for their efforts. Can the technology that put astronauts on the moon, split the atom, and eradicated most dreaded diseases be enlisted in this critical battle?

Unfortunately, science cannot offer final and authoritative solutions to problems that stem from a maze of social and psychological factors. However, as the content of this book attests, science occupies an important and unique role in the criminal justice system—a role that relates to the scientist's ability to supply accurate and objective information about the events that have occurred at a crime scene. A good deal of work remains to be done if the full potential of science as applied to criminal investigations is to be realized.

Because of the vast array of civil and criminal laws that regulate society, forensic science, in its broadest sense, has become so comprehensive a subject that a meaningful introductory textbook treating its role and techniques would be difficult to create and probably overwhelming to read. For this reason, we have narrowed the scope of the subject according to the most common definition: **Forensic science is the application of science to the criminal and civil laws that are enforced by police agencies in a criminal justice system.** *Forensic science* is an umbrella term encompassing a myriad of professions that use their skills to aid law enforcement officials in conducting their investigations.

The diversity of professions practicing forensic science is illustrated by the 11 sections of the American Academy of Forensic Science, the largest forensic science organization in the world:

1. Criminalistics
2. Digital and Multimedia Sciences
3. Engineering Science
4. General
5. Jurisprudence
6. Odontology
7. Pathology/Biology
8. Physical Anthropology
9. Psychiatry/Behavioral Science
10. Questioned Documents
11. Toxicology

Even this list of professions is not exclusive. It does not encompass skills such as fingerprint examination, firearm and tool mark examination, and photography.

Obviously, to author a book covering all of the major activities of forensic science as they apply to the enforcement of criminal and civil laws by police agencies would be a major undertaking. Thus, this book will further restrict itself to discussions of the subjects of chemistry,

biology, physics, geology, and computer technology, which are useful for determining the evidential value of crime-scene and related evidence. Forensic psychology, anthropology, and odontology also encompass important and relevant areas of knowledge and practice in law enforcement, each being an integral part of the total forensic science service that is provided to any up-to-date criminal justice system. However, these subjects go beyond the intended scope of this book, and except for brief discussions, along with pointing the reader to relevant websites, the reader is referred elsewhere for discussions of their applications and techniques. Instead, this book focuses on the services of what has popularly become known as the crime laboratory, where the principles and techniques of the physical and natural sciences are practiced and applied to the analysis of crime-scene evidence.

For many, the term *criminalistics* seems more descriptive than *forensic science* for describing the services of a crime laboratory. Regardless of his or her title—criminalist or forensic scientist—the trend of events has made the scientist in the crime laboratory an active participant in the criminal justice system.

Prime-time television shows like *CSI: Crime Scene Investigation* have greatly increased the public's awareness of the use of science in criminal and civil investigations (Figure 1–1). However, by simplifying scientific procedures to fit the allotted airtime, these shows have created within both the public and the legal community unrealistic expectations of forensic science. In these shows, members of the CSI team collect evidence at the crime scene, process all evidence, question witnesses, interrogate suspects, carry out search warrants, and testify in court. In the real world, these tasks are almost always delegated to different people in different parts of the criminal justice system. Procedures that in reality could take days, weeks, months, or years appear on these shows to take mere minutes. This false image is significantly responsible for the public's high interest in and expectations for DNA evidence.

The dramatization of forensic science on television has led the public to believe that every crime scene will yield forensic evidence, and it produces unrealistic expectations that a prosecutor's case should always be bolstered and supported by forensic evidence. This phenomenon is known as the “CSI effect.” Some jurists have come to believe that this phenomenon ultimately detracts from the search for truth and justice in the courtroom.



EL UNIVERSAL/Special Agency/SUN/Newscom

FIGURE 1–1

A scene from *CSI*, a forensic science television show.

History and Development of Forensic Science

Forensic science owes its origins first to the individuals who developed the principles and techniques needed to identify or compare physical evidence and second to those who recognized the need to merge these principles into a coherent discipline that could be practically applied to a criminal justice system.

Literary Roots

Today many believe that Sir Arthur Conan Doyle had a considerable influence on popularizing scientific crime-detection methods through his fictional character Sherlock Holmes (see Figure 1–2), who first applied the newly developing principles of serology (see Chapter 14), fingerprinting, firearms identification, and questioned document examination long before their value was first recognized and accepted by real-life criminal investigators. Holmes’s feats excited the imagination of an emerging generation of forensic scientists and criminal investigators. Even in the first Sherlock Holmes novel, *A Study in Scarlet*, published in 1887, we find examples of Doyle’s uncanny ability to describe scientific methods of detection years before they were actually discovered and implemented. For instance, here Holmes probes and recognizes the potential usefulness of forensic serology to criminal investigation:

“I’ve found it. I’ve found it,” he shouted to my companion, running towards us with a test tube in his hand. “I have found a reagent which is precipitated by hemoglobin and by nothing else. . . . Why, man, it is the most practical medico-legal discovery for years. Don’t you see that it gives us an infallible test for blood stains?. . . The old guaiacum test was very clumsy and uncertain. So is the microscopic examination for blood corpuscles. The latter is valueless if the stains are a few hours old. Now, this appears to act as well whether the blood is old or new. Had this test been invented, there are hundreds of men now walking the earth who would long ago have paid the penalty of their crimes. . . . Criminal cases are continually hinging upon that one point. A man is suspected of a crime months perhaps after it has been committed. His linen or clothes are examined and brownish stains discovered upon them. Are they blood stains, or rust stains, or fruit stains, or what are they? That is a question which has puzzled many an expert, and why? Because there was no reliable test. Now we have the Sherlock Holmes test, and there will no longer be any difficulty.”

Important Contributors to Forensic Science

Many people can be cited for their specific contributions to the field of forensic science. The following is just a brief list of those who made the earliest contributions to formulating the disciplines that now constitute forensic science.

MATHIEU ORFILA (1787–1853) Orfila is considered the father of forensic toxicology. A native of Spain, he ultimately became a renowned teacher of medicine in France. In 1814, Orfila published the first scientific treatise on the detection of poisons and their effects on animals. This treatise established forensic toxicology as a legitimate scientific endeavor.

ALPHONSE BERTILLON (1853–1914) Bertillon devised the first scientific system of personal identification. In 1879, Bertillon began to develop the science of *anthropometry* (see Chapter 6), a systematic procedure of taking a series of body measurements as a means of distinguishing one individual from another (see Figure 1–3).



Paul Chauncey/Alamy Stock Photo

FIGURE 1–2

Sir Arthur Conan Doyle’s legendary detective Sherlock Holmes applied many of the principles of modern forensic science long before they were adopted widely by police.



Courtesy Sirchie Fingerprint Laboratories, Youngsville, NC. www.sirchie.com

FIGURE 1-3
Bertillon's system of bodily measurements as used for the identification of an individual.

For nearly two decades, this system was considered the most accurate method of personal identification. Although anthropometry was eventually replaced by fingerprinting in the early 1900s, Bertillon's early efforts have earned him the distinction of being known as the father of criminal identification.

FRANCIS GALTON (1822–1911) Galton undertook the first definitive study of fingerprints and developed a methodology of classifying them for filing. In 1892, he published a book titled *Finger Prints*, which contained the first statistical proof supporting the uniqueness of his method of personal identification. His work went on to describe the basic principles that form the present system of identification by fingerprints.

LEONE LATTES (1887–1954) In 1901, Dr. Karl Landsteiner discovered that blood can be grouped into different categories. These blood groups or types are now recognized as A, B, AB, and O. The possibility that blood grouping could be a useful characteristic for the identification of an individual intrigued Dr. Lattes, a professor at the Institute of Forensic Medicine at the University of Turin in Italy. In 1915, he devised a relatively simple procedure for determining the blood group of a dried bloodstain, a technique that he immediately applied to criminal investigations.

CALVIN GODDARD (1891–1955) To determine whether a particular gun has fired a bullet requires a comparison of the bullet with one that has been test-fired from the suspect's weapon. Goddard, a U.S. Army colonel, refined the techniques of such an examination by using the comparison microscope. From the mid-1920s on, Goddard's expertise established the comparison microscope as the indispensable tool of the modern firearms examiner.

ALBERT S. OSBORN (1858–1946) Osborn's development of the fundamental principles of document examination was responsible for the acceptance of documents as scientific evidence by the courts. In 1910, Osborn authored the first significant text in this field, *Questioned Documents*. This book is still considered a primary reference for document examiners.

WALTER C. MCCRONE (1916–2002) Dr. McCrone's career paralleled startling advances in sophisticated analytical technology. Nevertheless, during his lifetime McCrone became the world's preeminent microscopist. Through his books, journal publications, and research institute, McCrone was a tireless advocate for applying microscopy to analytical problems, particularly forensic science cases. McCrone's exceptional communication skills made him a much-sought-after instructor, and he was responsible for educating thousands of forensic scientists throughout the world in the application of microscopic techniques. Dr. McCrone used microscopy, often in conjunction with other analytical methodologies, to examine evidence in thousands of criminal and civil cases throughout a long and illustrious career.

HANS GROSS (1847–1915) Gross wrote the first treatise describing the application of scientific disciplines to the field of criminal investigation in 1893. A public prosecutor and judge in Graz, Austria, Gross spent many years studying and developing principles of criminal investigation. In his classic book *Handbuch für Untersuchungsrichter als System der Kriminalistik* (later published in English under the title *Criminal Investigation*), he detailed the assistance that investigators could expect from the fields of microscopy, chemistry, physics, mineralogy, zoology, botany, anthropometry, and fingerprinting. He later introduced the forensic journal *Archiv für Kriminal Anthropologie und Kriminalistik*, which still serves as a medium for reporting improved methods of scientific crime detection.

EDMOND LOCARD (1877–1966) Although Gross was a strong advocate of the use of the scientific method in criminal investigation, he did not make any specific technical contributions to this philosophy. Locard, a Frenchman, demonstrated how the principles enunciated by Gross could be incorporated within a workable crime laboratory. Locard's formal education was in both medicine and law. In 1910, he persuaded the Lyons police department to give him two attic rooms and two assistants to start a police laboratory.

During Locard's first years of work, the only available instruments were a microscope and a rudimentary spectrometer. However, his enthusiasm quickly overcame the technical and monetary deficiencies he encountered. From these modest beginnings, Locard's research and

accomplishments became known throughout the world by forensic scientists and criminal investigators. Eventually he became the founder and director of the Institute of Criminalistics at the University of Lyons; this quickly developed into a leading international center for study and research in forensic science.

Locard believed that when a person comes in contact with an object or person, a cross-transfer of materials occurs (**Locard's exchange principle**). Locard maintained that every criminal can be connected to a crime by dust particles carried from the crime scene. This concept was reinforced by a series of successful and well-publicized investigations. In one case, presented with counterfeit coins and the names of three suspects, Locard urged the police to bring the suspects' clothing to his laboratory. On careful examination, he located small metallic particles in all the garments. Chemical analysis revealed that the particles and coins were composed of exactly the same metallic elements. Confronted with this evidence, the suspects were arrested and soon confessed to the crime. After World War I, Locard's successes served as an impetus for the formation of police laboratories in Vienna, Berlin, Sweden, Finland, and Holland.

Locard's exchange principle

Whenever two objects come into contact with one another, there is exchange of materials between them.

Crime Laboratories

The most ambitious commitment to forensic science occurred in the United States with the systematic development of national and state crime laboratories. This development greatly hastened the progress of forensic science.

Crime Labs in the United States

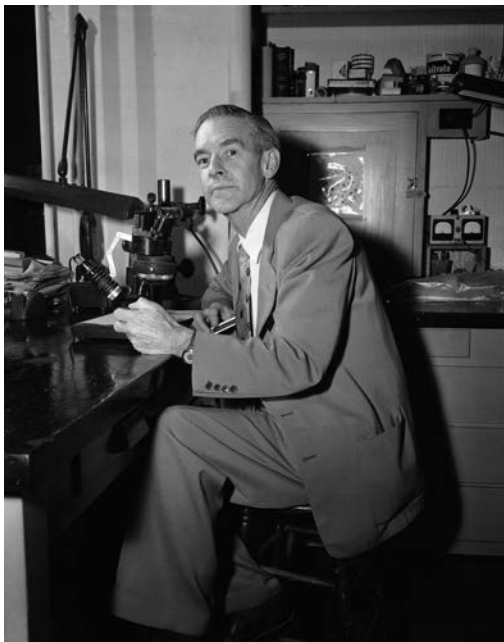
In 1932, the Federal Bureau of Investigation (FBI), under the directorship of J. Edgar Hoover, organized a national laboratory that offered forensic services to all law enforcement agencies in the country. During its formative stages, agents consulted extensively with business executives, manufacturers, and scientists whose knowledge and experience were useful in guiding the new facility through its infancy. The FBI Laboratory is now the world's largest forensic laboratory, performing more than one million examinations every year. Its accomplishments have earned it worldwide recognition, and its structure and organization have served as a model for forensic laboratories formed at the state and local levels in the United States as well as in other countries. Furthermore, the opening of the FBI's Forensic Science Research and Training Center in 1981

gave the United States, for the first time, a facility dedicated to conducting research to develop new and reliable scientific methods that can be applied to forensic science. This facility is also used to train crime laboratory personnel in the latest forensic science techniques and methods.

The oldest forensic laboratory in the United States is that of the Los Angeles Police Department, created in 1923 by August Vollmer, a police chief from Berkeley, California. In the 1930s, Vollmer headed the first U.S. university institute for criminology and criminalistics at the University of California at Berkeley. However, this institute lacked any official status in the university until 1948, when a school of criminology was formed. The famous criminalist Paul Kirk (see Figure 1–4) was selected to head its criminalistics department. Many graduates of this school have gone on to help develop forensic laboratories in other parts of the state and country.

California has numerous federal, state, county, and city crime laboratories, many of which operate independently. However, in 1972 the California Department of Justice embarked on an ambitious plan to create a network of state-operated crime laboratories. As a result, California has created a model system of integrated forensic laboratories consisting of regional and satellite facilities. An informal exchange of information and expertise is facilitated among California's criminalist community through a regional professional society, the California Association of Criminalists. This organization was the forerunner of a number of regional organizations that have developed throughout the United States to foster cooperation among the nation's growing community of criminalists.

The publication of *Strengthening Forensic Science in the United States* in 2009 by the National Academy of Sciences has served as a catalyst for



Bettmann/Getty Images

FIGURE 1–4

Paul Leland Kirk, 1902–1970.

improving the quality of research and development and standardization in the forensic sciences. The National Institute for Standards and Technology (NIST) within the Department of Commerce has emerged as a leading governmental agency in promoting the objectives advocated by *Forensic Science: A Path Forward*. Currently, NIST is active in these efforts by co-chairing the National Commission of Forensic Science within the Department of Justice which is aimed at coordinating federal policies surrounding the practice of forensic science. It also leads the Organization of Scientific Area Committees (OSAC) a series of committees and subcommittees designed to standardize forensic practices across numerous forensic science disciplines. NIST also has an active forensic research program carried out within the institute.

International Crime Labs

In contrast to the American system of independent local laboratories, Great Britain had developed a national system of regional laboratories under the direction of the government's Home Office. In the early 1990s, the British Home Office reorganized the country's forensic laboratories into the Forensic Science Service and instituted a system in which police agencies are charged a fee for services rendered by the laboratory. The fee-for-service concept encouraged the creation of a number of private laboratories that provide services to both police and criminal defense attorneys. One such organization is LGC. In 2010, the British government announced the closure of the Forensic Science Service, citing financial losses. The laboratories closed in 2012, and forensic work in England and Wales is now contracted out to the private sector. Since privatization, LGC has grown to be the largest forensic science provider in the United Kingdom, employing more than 700 forensic scientists servicing both police agencies and the private sector.

In Canada, forensic services are provided by three government-funded institutes: (1) three Royal Canadian Mounted Police regional laboratories, (2) the Centre of Forensic Sciences in Toronto, and (3) the Institute of Legal Medicine and Police Science in Montreal. The Royal Canadian Mounted Police opened its first laboratory in Regina, Saskatchewan, in 1937. Altogether, more than a hundred countries throughout the world have at least one laboratory facility offering services in the field of forensic science.

Organization of a Crime Laboratory

The development of crime laboratories in the United States has been characterized by rapid growth accompanied by a lack of national and regional planning and coordination. It is estimated that more than 411 publicly funded crime laboratories currently operate at various levels of government (federal, state, county, and municipal)—more than three times the number of crime laboratories operating in 1966. They employ more than 14,000 full-time personnel.

The size and diversity of crime laboratories make it impossible to select any one model that best describes a typical crime laboratory. Although most of these facilities function as part of a police department, others operate under the direction of the prosecutor's or district attorney's office; some work with the laboratories of the medical examiner or coroner. Far fewer are affiliated with universities or exist as independent agencies in government. Laboratory staff sizes range from one person to more than a hundred, and their services may be diverse or specialized, depending on the responsibilities of the agency that houses the laboratory.

The Growth of Crime Laboratories

Crime laboratories have mostly been organized by agencies that either foresaw their potential application to criminal investigation or were pressed by the increasing demands of casework. Several reasons explain the unparalleled growth of crime laboratories during the past 35 years. Supreme Court decisions in the 1960s were responsible for greater police emphasis on securing scientifically evaluated evidence. The requirement to advise criminal suspects of their constitutional rights and their right of immediate access to counsel has all but eliminated confessions as a routine investigative tool. Successful prosecution of criminal cases requires a thorough and professional police investigation, frequently incorporating the skills of forensic science experts. Modern technology has provided forensic scientists with many new skills and techniques to meet the challenges accompanying their increased participation in the criminal justice system.