

THIRD EDITION

FORENSIC SCIENCE An Introduction

RICHARD SAFERSTEIN

Taken from:

Forensic Science: An Introduction, Second Edition

Forensic Science: From the Crime Scene to the Crime Lab, Third Edition

Criminalistics: An Introduction to Forensic Science, Eleventh Edition
by Richard Saferstein

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by Richard Saferstein

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Published by Pearson Prentice Hall

Upper Saddle River, New Jersey 07458

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Pearson, Inc., 501 Boylston Street, Suite 900, Boston, MA 02116

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Printed in the United States of America

1 2 3 4 5 6 7 8 9 10 XXXX 18 17 16 15 14

000200010271883662

RP/MT

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ISBN 10: 1-269-92520-2 (HS Binding)
ISBN 13: 978-1-269-92520-4 (HS Binding)

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To my wife, Gail, pillar of my life

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Preface

The level of sophistication that forensic science has brought to criminal investigations is awesome. But one cannot lose sight of the fact that, once all the drama of a forensic science case is put aside, what remains is an academic subject emphasizing science and technology. It is to this end that this third edition of *Forensic Science: An Introduction* is dedicated.

This high school edition follows the tradition, philosophy, and objectives of my introductory college text, *Criminalistics: An Introduction to Forensic Science*, which is in its eleventh edition. In creating this introductory text, every chapter of the college text was examined to improve the clarity of the narrative. This improvement has been accomplished by presenting the science of forensics in a straightforward and student-friendly format. Topics have been rearranged to better integrate scientific methodology with actual forensic application. The reader is offered the option of delving into the more difficult technical aspects of the book by going into the “Inside the Science” features in some chapters, an option that can be bypassed without detracting from a basic comprehension of the subject of forensic science.

Only the most relevant scientific and technological concepts are presented to the reader, so that the subject is not watered down with superfluous discussions that are of no real significance to current forensic science practices. It is the author’s belief that, by learning in an interactive environment using the Internet, the reader will be a more motivated and active participant in the learning process. The text is accompanied by a companion website that provides additional exercises, text information, and MyCrimeLab: WebExtras. The latter serve to expand the coverage of the book through video presentations and MyCrimeLab: WebExtras that enhance the reader’s understanding of the subject’s more difficult concepts.

One of the constants of forensic science is how frequently its applications become front-page news. Whether the story is sniper shootings or the tragic consequences of the terrorist attacks of 9/11/01, forensic science is at the forefront of the public response. In order to merge theory with practice, a significant number of actual forensic Case Files are included in the text. The intent is for all the case illustrations to capture the interest of the reader and to move forensic science from the domain of the abstract into the real world of criminal investigation.

Within and at the end of each chapter, the student will encounter Quick Reviews and a Chapter Summary that recap all of the major points of the chapter. The end-of-chapter summary is followed by review questions, as well as application and critical thinking exercises designed to have the reader further explore the chapter’s content and its significance. Most chapters also include Laboratory Experiments, which have students apply the Next Generation Science Standards to a crime-scene activity. In some chapters, virtual crime scene exercises enable the reader to move through various types of crime scenes while identifying and collecting physical evidence.

Acknowledgments

I am most appreciative of the contribution that Lieutenant Andrew (Drew) Donofrio of New Jersey's Bergen County Prosecutor's Office made to *Forensic Science*. I was fortunate to find in Drew a contributor who not only possesses extraordinary skill, knowledge, and hands-on experience with computer forensics, but who was able to combine those attributes with sophisticated communication skills. Likewise, I was fortunate to have Dr. Peter Stephenson contribute to this book on the subject of mobile forensics. He brings skills as a cybercriminologist, author, and educator in digital forensics.

Sarah A. Skorupsky-Borg, MSFS, invested an extraordinary amount of time and effort in preparing an accompanying supplement to this text: *Basic Laboratory Exercises for Forensic Science*. Her skills and tenacity in carrying out this task are acknowledged and greatly appreciated.

Many people provided assistance and advice in the preparation of this book. Many faculty members, colleagues, and friends have read and commented on various portions of the text. I would like to acknowledge the contributions of Anita Wonder, Robert J. Phillips, Norman H. Reeves, Jeffrey C. Kercheval, Robert Thompson, Roger Ely, Jose R. Almirall, Michael Malone, Ronald Welsh, Ken Radwill, David Pauly, Jan Johnson, Natalie Borgan, Dr. Barbara Needell, Robin D. Williams, Peter Diaczuk, and Jacqueline E. Joseph. I'm appreciative of the contributions, reviews, and comments that Dr. Claus Speth, Dr. Mark Taff, Dr. Elizabeth Laposata, Thomas P. Mauriello, and Michelle D. Miranda provided during the preparation of Chapter 4, "Death Investigation."

I'm appreciative of the efforts of Brenda Wolpa and Jill Christman in preparing chapter experiments that support the Next Generation Science Standards.

Thanks to the reviewers of the third edition for their feedback: Debbie Allen, Maury High School; Jennifer Bisch, St. Joseph's Academy; Tommy Decker, Thomas Jefferson High School; Aimee Fydyuk, Hillsboro High School; Terry Howerton, Atkins High School; Derrick Leach, Mid-East Career and Technology; Keith Miessau, Lake Mary High School; Scott Rubins, New Rochelle High School; and Brenda Wolpa, Salpointe Catholic High School. The following reviewers for the second edition provided insightful and helpful critiques of the manuscript: Kate Allender, Redmond High School; Jill Christman, Canyon Del Oro High School; Charles Fanning, La Habra High School; John Gomola, Sterling Heights High School; Lance Goodlock, Sturgis High School; Dorothy Harris, Quince Orchard High School; Christine Leventhal, Darien High School; Christal Lippencott, Parker High School; Mary Monte, Eastern Technical High School; Kim McNamara, Oak Lawn Community High School; Randy Neider, Reading High School; Stephanie Niedermeyer, Wayne Memorial High School; Baokhanh Paton, Granby Memorial High School; and Jay Phillips, Westside High School.

I also thank the following reviewers of the first edition: Craig Anderson, Galt High School; Margaret Barthel, Ph.D., Freedom High School; Thomas J. Costello, High Point Regional High School; Thomas Donley, The Hotchkiss School; Shelly Duk, Walled Lake Central High School; Mark Feil, Glasgow High School; Myra Frank, Marjory Stoneman Douglas High School; Jim Hurley, Waverly-Shell Rock Community Schools; Lisa Kiann, River Valley High School; Mary Monte, Eastern Technical High School; Mary J. Monte, Woodlawn High School; Kevin Mugridge, Bishop Timon St. Jude High School; Barbara Olsen, Rocky Hill High School; Bruce Parce, Albert Einstein High School; Tod Suttle, Mayfair Middle/High School; Danielle DuChesne Thompson, Mariner High School; and Penny Wolkow, Oakland Mills High School.

The assistance and research efforts of Pamela Cook, Gonul Turhan, and Michelle Tetreault were invaluable and are an integral part of this text. The transformation of *Criminalistics* from a college text into this edition is the result in large part of the editorial skills of John Haley, who reorganized substantial portions of the text and rewrote end-of-chapter questions.

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

About the Author

Richard Saferstein, Ph.D., retired in 1991 after serving twenty-one 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 its eleventh 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 forty-four technical papers covering a variety of forensic topics. Dr. Saferstein has authored *Basic Laboratory Exercises for Forensic Science* (Prentice Hall, 2011) and co-authored *Lab Manual for Criminalistics* (Prentice Hall, 2015). He has also edited two editions of the widely used professional reference books *Forensic Science Handbook, Volume 1* (Prentice Hall, 2002), *Forensic Science Handbook, Volume 2* (Prentice Hall, 2005), and *Forensic Science Handbook, Volume 3* (Prentice Hall, 2009). 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.

In 2006, Dr. Saferstein received the American Academy of Forensic Sciences Paul L. Kirk award for distinguished service and contributions to the field of criminalistics.

Handbook of Forensic Services—FBI

The *Handbook of Forensic Services* provides guidance and procedures for the safe and efficient methods of collecting, preserving, packaging, and shipping evidence, and describes the forensic examinations performed by the FBI's Laboratory Division and Operational Technology Division.

The contents of the Handbook are to be found by the reader on either the iPhone app entitled “FBI Handbook” or the Android app entitled “Handbook of Forensic Services.” The handbook can also be found online: www.fbi.gov/about-us/lab/handbook-of-forensic-services-pdf.

Next Generation Science Standards* Overview

The Next Generation Science Standards (NGSS) provide an important opportunity to improve not only science education but also student achievement. Based on the Framework for K–12 Science Education, the NGSS are intended to reflect a new vision for American science Education

The forensic science course, being an integrated science, is not intended to directly address specific NGSS expectations. However, it incorporates the science and engineering practices and crosscutting concepts from the Framework for K–12 Science Education, which are the foundation for the NGSS standards.

The Framework identifies seven crosscutting concepts and eight science and engineering practices. The seven crosscutting concepts bridge disciplinary boundaries, uniting core ideas throughout the fields of science and engineering. The seven crosscutting concepts are as follows.

1. **Patterns**—Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. **Cause and effect: Mechanism and explanation**—Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. **Scale, proportion, and quantity**—In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.
4. **Systems and system models**—Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. **Energy and matter: Flows, cycles, and conservation**—Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations.
6. **Structure and function**—The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. **Stability and change**—For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

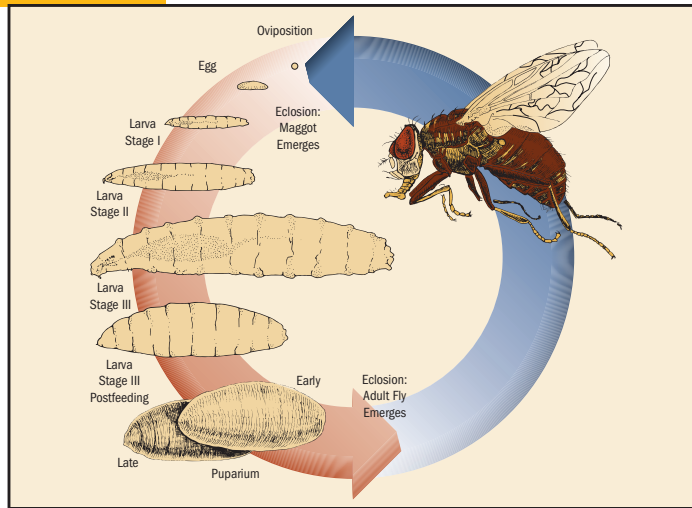
The eight practices of science and engineering identified as essential for all students to learn are listed below:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

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Dimensional Illustrations

The full-color art program helps students better understand key forensics concepts.



Open and Accessible Design

496 Chapter 13

Trace Evidence II: Metals, Paint, and Soil 497

animation graphically showed that the bullet wounds were completely consistent with Kennedy's and Connally's positions at the time of shooting, and that by following the bullet's trajectory backward they could be found to have originated from a narrow cone including only a few windows of the sixth floor of the Texas School Book Depository.

Atomic Structure

To understand the principle behind neutron activation analysis, one must first understand the fundamental structure of the atom. Each atom is composed of elementary particles that are collectively known as subatomic particles. The most important subatomic particles are the **proton**, **electron**, and **neutron**.

The properties of the proton, neutron, and electron are summarized in the following table:

Particle	Symbol	Relative Mass	Electrical Charge
Proton	p	1	+
Neutron	n	1	0
Electron	e	1/1837	-

As you can see, the masses of the proton and neutron are each about 1,837 times the mass of an electron. The proton has a positive electrical charge; the electron has a negative charge equal in magnitude to that of the proton; and the neutron is a neutral particle with neither a positive nor a negative charge.

A popular descriptive model of the atom, and the one that will be adopted for the purposes of this discussion, pictures an atom as consisting of electrons orbiting a central **nucleus** composed of protons and neutrons—an image that is analogous to our solar system, in which the planets revolve around the sun (see Figure 13-4).¹ To maintain a zero net electrical charge, the number of protons in the nucleus must always equal the number of electrons in orbit around the nucleus.

FIGURE 13-4
A popular model of the atom shows the electrons in planets orbiting the "sun" of the nucleus. Courtesy: Getty Images - Stone Alliance

With this knowledge, we can describe the atomic structure of the elements. For example, hydrogen has a nucleus consisting of one proton and no neutrons, and it has one orbiting electron. Helium has a nucleus comprising two protons and two neutrons, with two electrons in orbit around the nucleus (see Figure 13-5).

FIGURE 13-5
The atomic structures of hydrogen and helium.

The behavior and properties that distinguish one element from another must be related to the differences in the atomic structure of each element. One such distinction is that each element possesses a different number of protons. This number is called the **atomic number** of the element. As we look back at the periodic table on page 156, we see that the elements are numbered consecutively. These numbers represent the atomic number or number of protons associated with each element. An element is therefore a collection of atoms that all have the same number of protons. Thus, each atom of hydrogen has one and only one proton, each atom of helium has 2 protons, each atom of silver has 47 protons, and each atom of lead has 82 protons in its nucleus.

Isotopes and Radioactivity

Although the atoms of a single element must have the same number of protons, nothing prevents them from having different numbers of neutrons. The total number of protons and neutrons in a nucleus is known as the **atomic mass number**. Atoms with the same number of protons but differing solely in the number of neutrons are called **isotopes**.

For example, hydrogen consists of three isotopes: ordinary hydrogen, which has one proton and no neutrons in its nucleus, and two other isotopes called deuterium and tritium. Deuterium (or heavy hydrogen) also has one proton, but contains one neutron as well. Tritium has one proton and two neutrons in its nucleus.

Therefore, all the isotopes of hydrogen have an atomic number of 1 but differ in their atomic mass numbers. Hydrogen has an atomic mass of 1, deuterium a mass of 2, and tritium a mass of 3. The atomic structures of these isotopes is shown in Figure 13-6.

FIGURE 13-6
Isotopes of hydrogen.

proton
A positively charged particle that is one of the basic structures in the nucleus of an atom.

electron
A negatively charged particle that is one of the fundamental structural units of the atom.

neutron
A particle with no electrical charge that is one of the basic structures in the nucleus of an atom.

nucleus
The core of an atom, consisting of protons and neutrons.

atomic number
The number of protons in the nucleus of an atom.

atomic mass
The sum of the number of protons and neutrons in the nucleus of an atom.

isotope
An atom differing from another atom of the same element in the number of neutrons it has in its nucleus.

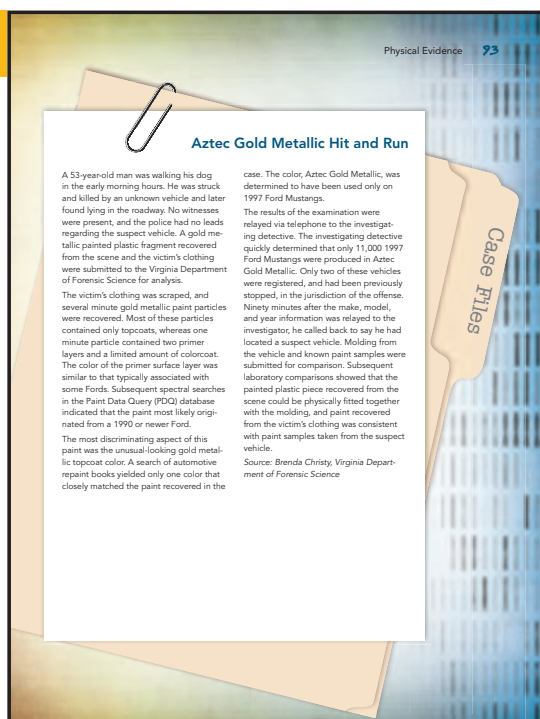
Design elements bring the course content to life and provide visual cues to guide student reading.

Key Terms

Forensic-specific vocabulary is highlighted in the text and defined in the margins.

Engaging Case Files

Linked to the chapter material, the Case File feature boxes provide students with quick and pertinent facts about real forensic cases.



Quick Labs

354 Chapter 9

Quick Lab: Luminol Test

Materials:

Luminol (powder needs to be mixed with water)
Spray bottle
Simulated blood
Piece of wood or flooring
UV light source

Procedure:

Apply some blood to the wood/flooring. Then try to completely clean it, as if you were trying to cover up a crime. If the teacher does not have the luminol mixed for you, follow instructions on how to mix it. Using the spray bottle, apply some luminol to the wood/flooring that you cleaned. Keep the room dark for this step. You may shine the UV light on the area where you sprayed the luminol; this may help if you do not see a reaction right away.

Follow-Up Questions:

1. Did you observe any reaction when the room was dark? When you shined the UV light on the wood/flooring? If so, what did you observe?
2. How does luminol detect bloodstains?
3. What is luminescence?

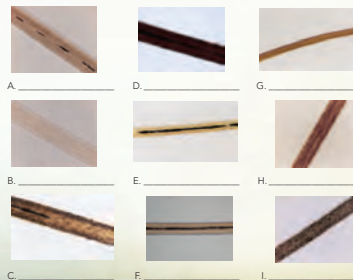
Inquiry is at the heart of science, and it's no exception here. In-text Quick Labs are hands-on activities that allow students to apply and experience key forensic concepts.

Application and Critical Thinking

Each chapter contains many activities designed to encourage application of critical thinking skills as they pertain to everyday life.

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 Evelt 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 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.



Courtesy Richard Saferstein, Ph.D.

Chapter Review and Assessment

Chapter Review

- Trace elements are small quantities of elements present in concentrations of less than 1 percent. They provide "invisible" markers that may establish the source of a material or provide additional points for comparison.
- The three most important subatomic particles are the proton, neutron, and electron. The proton has a positive electrical charge, the neutron has no electrical charge, and the electron has a negative electrical charge.
- Atomic number indicates the number of protons in the nucleus of an atom. Atomic mass refers to the total number of protons and neutrons in a nucleus.
- An isotope is an atom differing from other atoms of the same element in the number of neutrons in its nucleus.
- Radioactivity is the emission of high-energy subatomic particles that accompanies the spontaneous disintegration of the nuclei of unstable isotopes. The three types of radiation are alpha particle rays, beta particle rays, and gamma rays.
- In neutron activation analysis, a sample is bombarded with neutrons and the energy of the gamma rays emitted by the activated isotopes is measured. The gamma rays of each element are associated with characteristic energy values that help identify the specific element that produces them.
- Paint spread onto a surface dries into a hard film that is best described as consisting of pigments and additives suspended in the binder.
- Questioned and known paint specimens are best compared side by side under a stereoscopic microscope for color, surface texture, and color layer sequence.
- Pyrolysis gas chromatography and infrared spectrophotometry are used to distinguish most paint binder formulations.
- Emission spectroscopy and inductively coupled plasma are techniques available for determining the elemental composition of paint pigments.
- PDQ (Paint Data Query) is a computerized database that allows an analyst to obtain information on paints related to automobile make, model, and year.
- A side-by-side visual comparison of the color and texture of soil specimens provides a way to distinguish soils that originate from different locations.
- Minerals are naturally occurring crystalline solids found in soil. Their physical properties—for example, color, geometric shape, density, and refractive index or birefringence—are useful for characterizing soils.

Each chapter provides a point-by-point summary of key concepts, with explanations that reinforce the materials covered.

New to This Edition

- New, enhanced, and current Case Files feature that links the content to real-world crime cases.
- New chapters on Death Investigation and Mobile Device Forensics.
- New end-of-chapter Laboratory Experiments that support Next Generation Science Standards.
- New photo program.

Student and Teacher Supplements

Basic Laboratory Exercises for Forensic Science

(Available for purchase, ISBN: 1-323-01928-6)

The *Basic Laboratory Exercises* workbook brings the real world of forensic science into the classroom with hands-on activities from fingerprinting to bloodstain analysis, and from forensic entomology to forensic anthropology.

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This is an online supplement that offers book-specific learning objectives, chapter summaries, flashcards, WebExtras, practice tests, and more to aid student learning and comprehension. In addition, the teacher resources for *Forensic Science*, 3e, are also included in this online supplement. These include the Annotated Teacher's Edition, videos, PowerPoints, and testing files. Access to MyCrimeLab with Pearson eText is provided upon adoption. See below for teacher and student access information.

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