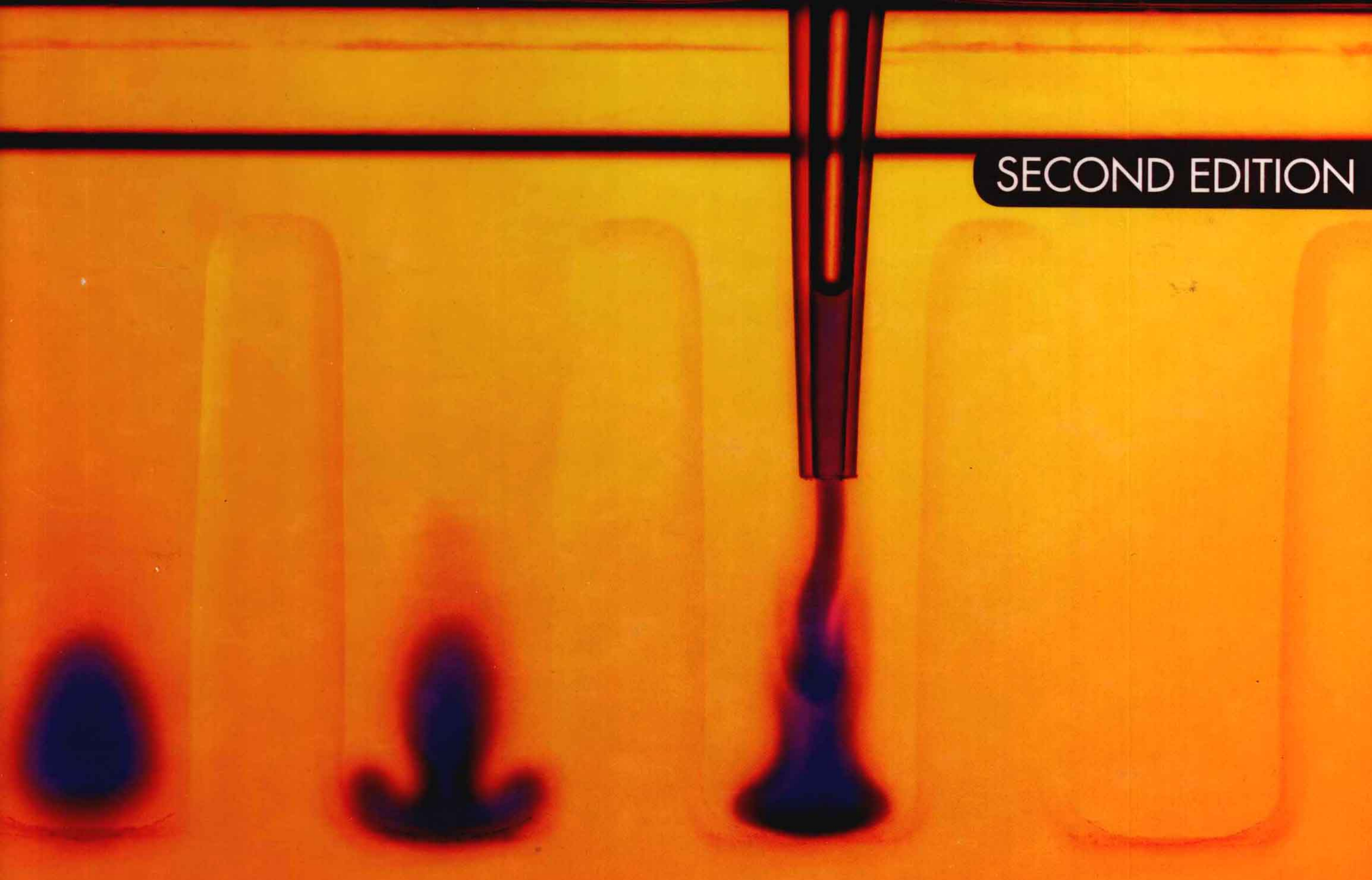

SECOND EDITION

ForensicScience

AN INTRODUCTION

RICHARD SAFERSTEIN

FORENSIC SCIENCE

An Introduction

Second Edition

Richard Saferstein, Ph.D.

Forensic Science Consultant, Mt. Laurel, New Jersey

Prentice Hall

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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 second edition of *Forensic Science: An Introduction* is dedicated.

This book follows the tradition, philosophy, and objectives of my introductory college text, *Criminalistics: An Introduction to Forensic Science*, which is in its tenth 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 web site that provides additional exercises, text information, and MyCrimeKit: WebExtras. The latter serve to expand the coverage of the book through video presentations and MyCrimeKit: Web Extras 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. 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.

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 Jeffrey C. Kercheval, Robert Thompson, Roger Ely, Jose R. Almirall, Darlene Brezinski, Gavin Edmonstone, Anita Wonder, Norman Reeves, and Michael Malone.

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 tenth 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.

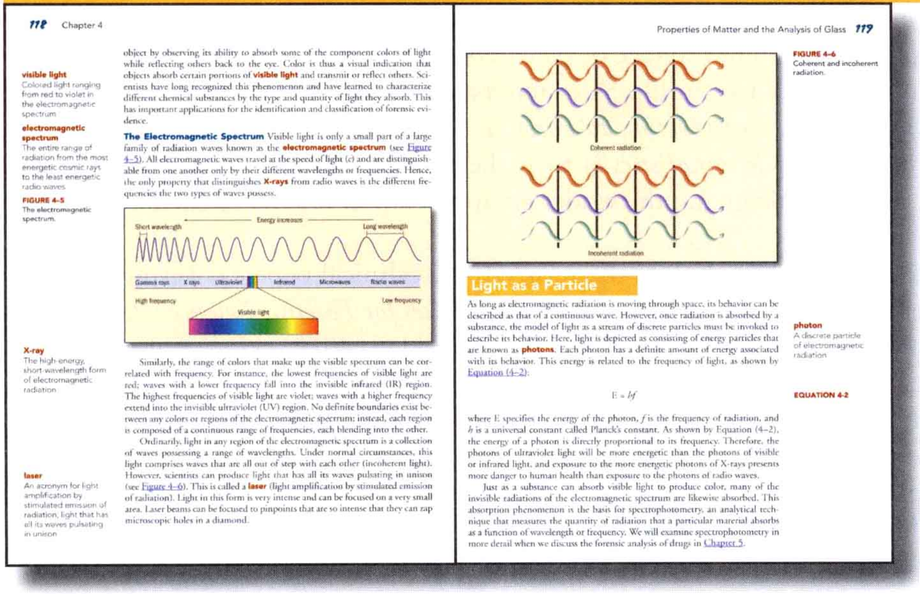
Dr. Saferstein has authored or co-authored more than forty-four technical papers covering a variety of forensic topics. Dr. Saferstein has authored *Basic Laboratory Exercises for Forensic Science* (Prentice Hall, 2011) and co-authored *Lab Manual for Criminalistics* (Prentice Hall, 2011). He has also 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 Mid-Atlantic Association of Forensic Scientists, the Northeastern Association of Forensic Scientists, the Northwestern 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.

Welcome...

to the exciting second edition of *Forensic Science: An Introduction*. Richard Saferstein has carefully adapted and updated his classic *Criminalistics* text to create a comprehensive program designed specifically for high school students and teachers.

Accessible Text and Motivational 4-Color Presentation



object by observing its ability to absorb some of the component colors of light while reflecting others back to the eye. Color is thus a visual indication that objects absorb certain portions of **visible light** and transmit or reflect others. Scientists have long recognized this phenomenon and have learned to characterize different chemical substances by the type and quantity of light they absorb. This has important applications for the identification and classification of forensic evidence.

visible light Colored light ranging from red to violet in the electromagnetic spectrum

electromagnetic spectrum The entire range of radiation from the most energetic cosmic rays to the least energetic radio waves

The Electromagnetic Spectrum Visible light is only a small part of a large family of radiation waves known as the **electromagnetic spectrum** (see Figure 4–5). All electromagnetic waves travel at the speed of light (c) and are distinguishable from one another only by their different wavelengths or frequencies. Hence, the only property that distinguishes **X-rays** from radio waves is the different frequencies the two types of waves possess.

FIGURE 4–5 The electromagnetic spectrum.

X-ray The high-energy, short-wavelength form of electromagnetic radiation

Similarly, the range of colors that make up the visible spectrum can be correlated with frequency. For instance, the lowest frequencies of visible light are red; waves with a lower frequency fall into the invisible infrared (IR) region. The highest frequencies of visible light are violet; waves with a higher frequency extend into the invisible ultraviolet (UV) region. No definite boundaries exist between any colors or regions of the electromagnetic spectrum; instead, each region is composed of a continuous range of frequencies, each blending into the other.

Ordinarily, light in any region of the electromagnetic spectrum is a collection of waves possessing a range of wavelengths. Under normal circumstances, this light comprises waves that are all out of step with each other (incoherent light). However, scientists can produce light that has all its waves pulsating in unison (see Figure 4–6). This is called a **laser** (light amplification by stimulated emission of radiation). Light in this form is very intense and can be focused on a very small area. Laser beams can be focused to pinpoints that are so intense that they can zap microscopic holes in a diamond.

laser An acronym for light amplification by stimulated emission of radiation; light that has all its waves pulsating in unison

FIGURE 4–6 Coherent and incoherent radiation.

Light as a Particle

As long as electromagnetic radiation is moving through space, its behavior can be described as that of a continuous wave. However, once radiation is absorbed by a substance, the model of light as a stream of discrete particles must be invoked to describe its behavior. Here, light is depicted as consisting of energy particles that are known as **photons**. Each photon has a definite amount of energy associated with its behavior. This energy is related to the frequency of light, as shown by Equation (4–2):

photon A discrete particle of electromagnetic radiation

$$E = hf$$

EQUATION 4-2

where E specifies the energy of the photon, f is the frequency of radiation, and h is a universal constant called Planck's constant. As shown by Equation (4–2), the energy of a photon is directly proportional to its frequency. Therefore, the photons of ultraviolet light will be more energetic than the photons of visible or infrared light, and exposure to the more energetic photons of X-rays presents more danger to human health than exposure to the photons of radio waves.

Just as a substance can absorb visible light to produce color, many of the invisible radiations of the electromagnetic spectrum are likewise absorbed. This absorption phenomenon is the basis for spectrophotometry, an analytical technique that measures the quantity of radiation that a particular material absorbs as a function of wavelength or frequency. We will examine spectrophotometry in more detail when we discuss the forensic analysis of drugs in Chapter 5.

The new layout and design make learning forensic science even more motivating and exciting.

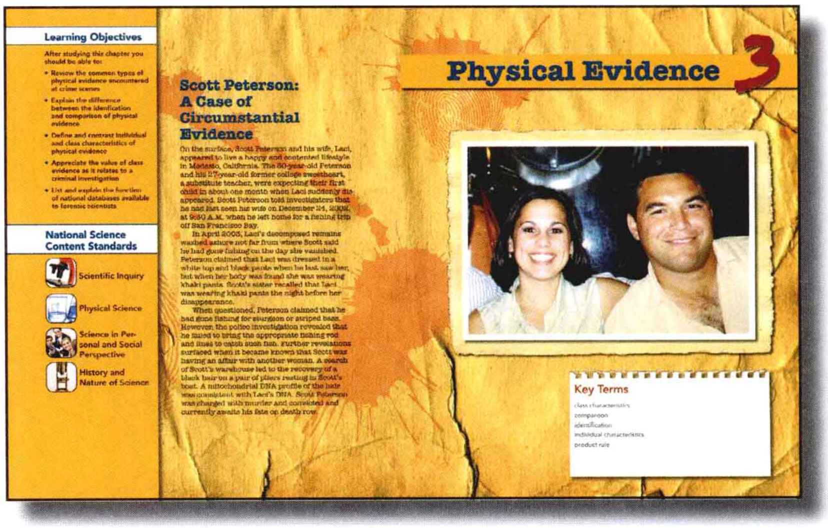
Students live in a visual world, and the functional use of full color conveys forensic science to today's students. Over 150 full-color photos and illustrations motivate students to read.

Chapter Openers

Each chapter opens with a real-life case study and stunning visual that captures students' interest and brings content to life.

Learning Objectives help students focus on the key takeaways for that chapter.

National Science Education Standards align with the chapter content and highlight the multidisciplinary nature of forensic science.


Learning Objectives

After studying this chapter you should be able to:

- Review the common types of physical evidence encountered at crime scenes
- Explain the difference between the idenfication and comparison of physical evidence
- Define and contrast individual and class characteristics of physical evidence
- Appreciate the value of class evidence as it relates to a criminal investigation
- List and explain the function of national databases available to forensic scientists

National Science Content Standards

Scientific Inquiry
Physical Science
Science in Personal and Social Perspective
History and Nature of Science

Scott Peterson: A Case of Circumstantial Evidence

On the surface, Scott Peterson and his wife, Laci, appeared to live a happy and contented lifestyle in Modesto, California. The 30-year-old Peterson and his 27-year-old former college sweetheart, a substitute teacher, were expecting their first child in about one month when Laci suddenly disappeared. Scott Peterson told investigators that he had last seen his wife on December 24, 2002, at 9:30 A.M. when he left home for a fishing trip off San Francisco Bay.

In April 2003, Laci's decomposed remains washed ashore not far from where Scott said he had gone fishing on the day she vanished. Peterson claimed that Laci was dressed in a white top and black pants when he last saw her, but when her body was found she was wearing khaki pants. Scott's sister recalled that Laci was wearing khaki pants the night before her disappearance.

When questioned, Peterson claimed that he had gone fishing for sturgeon or striped bass. However, the police investigation revealed that he failed to bring the appropriate fishing rod and lines to catch such fish. Further revelations surfaced when it became known that Scott was having an affair with another woman. A search of Scott's warehouse led to the recovery of a black hair on a pair of pliers resting in Scott's boat. A mitochondrial DNA profile of the hair was consistent with Laci's DNA. Scott Peterson was charged with murder and convicted and currently awaits his fate on death row.

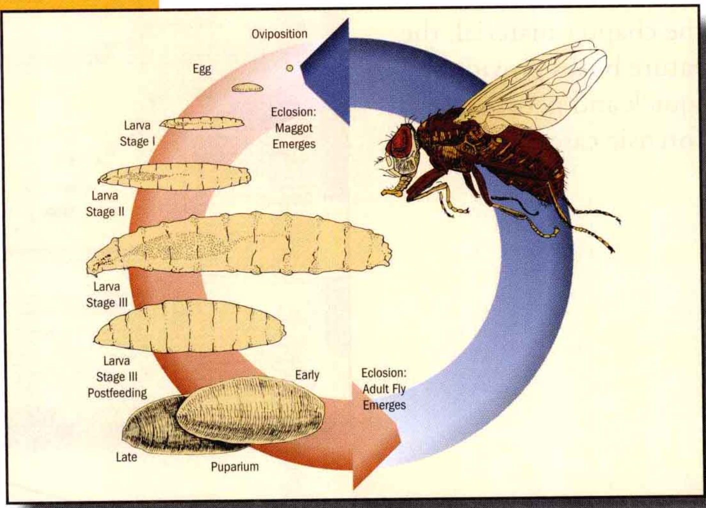
Physical Evidence 3

Key Terms

class characteristics
comparison
identification
individual characteristics
product rule

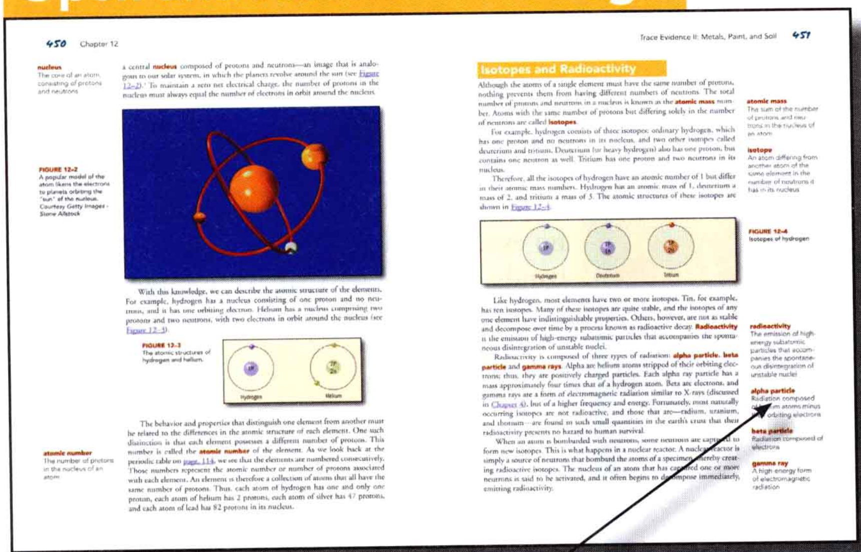
Dimensional Illustrations

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



Open and Accessible Design

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



450 Chapter 12

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

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 12-2).[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 12-2
A popular model of the atom likens the electrons to planets orbiting the "sun" of the nucleus. Courtesy Getty Images - Stone Allstock

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 12-3).

FIGURE 12-3
The atomic structures of hydrogen and helium.

Hydrogen
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 114, we see that the elements are numbered consecutively. Those 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.

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

Trace Evidence II: Metals, Paint, and Soil 451

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**.

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

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 are shown in Figure 12-4.

FIGURE 12-4
Isotopes of hydrogen

Hydrogen
Deuterium
Tritium

Like hydrogen, most elements have two or more isotopes. Tin, for example, has ten isotopes. Many of these isotopes are quite stable, and the isotopes of any one element have indistinguishable properties. Others, however, are not as stable and decompose over time by a process known as radioactive decay. **Radioactivity** is the emission of high-energy subatomic particles that accompanies the spontaneous disintegration of unstable nuclei.

radioactivity
The emission of high-energy subatomic particles that accompanies the spontaneous disintegration of unstable nuclei

Radioactivity is composed of three types of radiation: **alpha particle**, **beta particle** and **gamma rays**. Alpha are helium atoms stripped of their orbiting electrons; thus, they are positively charged particles. Each alpha ray particle has a mass approximately four times that of a hydrogen atom. Beta are electrons, and gamma rays are a form of electromagnetic radiation similar to X-rays (discussed in Chapter 4), but of a higher frequency and energy. Fortunately, most naturally occurring isotopes are not radioactive, and those that are—radium, uranium, and thorium—are found in such small quantities in the earth's crust that their radioactivity presents no hazard to human survival.

alpha particle
Radiation composed of helium atoms minus their orbiting electrons

beta particle
Radiation composed of electrons

gamma ray
A high energy form of electromagnetic radiation

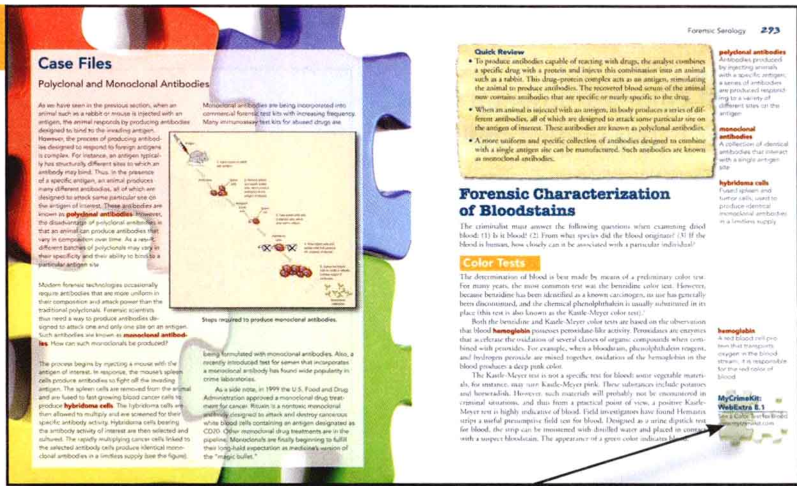
When an atom is bombarded with neutrons, some neutrons are captured to form new isotopes. This is what happens in a nuclear reactor. A nuclear reactor is simply a source of neutrons that bombard the atoms of a specimen, thereby creating radioactive isotopes. The nucleus of an atom that has captured one or more neutrons is said to be activated, and it often begins to decompose immediately, emitting radioactivity.

Key Terms

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

Engaging Case Files

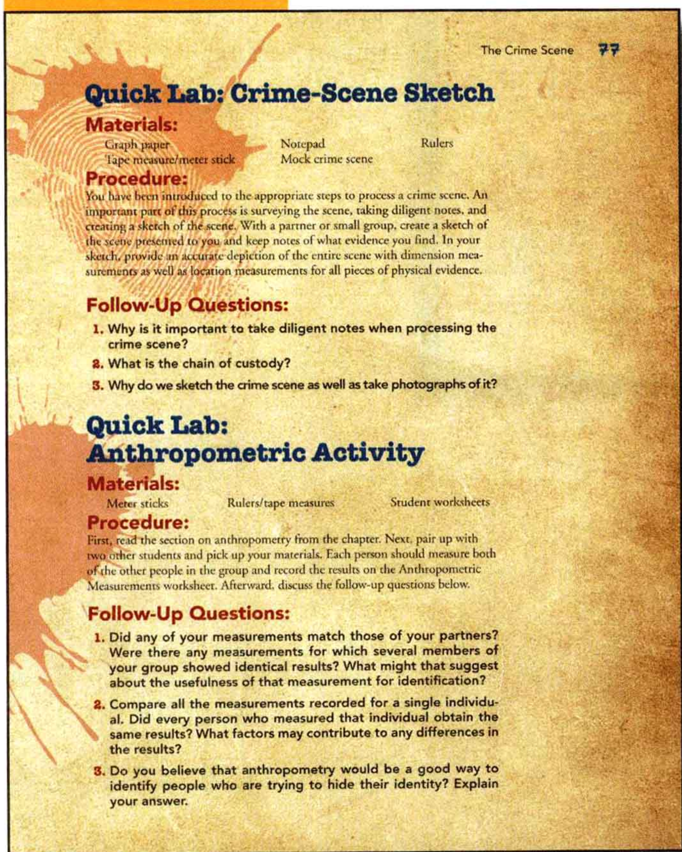
Linked to the chapter material, the Case File feature boxes provide students with quick and pertinent facts about real forensic cases.



WebExtras

Interactive activities and in-depth information are just a click away. Hand-picked by the author, WebExtras drive students online to explore a wide range of forensic topics in greater depth.

Quick Labs



The Crime Scene 77

Quick Lab: Crime-Scene Sketch

Materials:

Graph paper
Tape measure/meter stick
Notepad
Mock crime scene
Rulers

Procedure:

You have been introduced to the appropriate steps to process a crime scene. An important part of this process is surveying the scene, taking diligent notes, and creating a sketch of the scene. With a partner or small group, create a sketch of the scene presented to you and keep notes of what evidence you find. In your sketch, provide an accurate depiction of the entire scene with dimension measurements as well as location measurements for all pieces of physical evidence.

Follow-Up Questions:

1. Why is it important to take diligent notes when processing the crime scene?
2. What is the chain of custody?
3. Why do we sketch the crime scene as well as take photographs of it?

Quick Lab: Anthropometric Activity

Materials:

Meter sticks
Rulers/tape measures
Student worksheets

Procedure:

First, read the section on anthropometry from the chapter. Next, pair up with two other students and pick up your materials. Each person should measure both of the other people in the group and record the results on the Anthropometric Measurements worksheet. Afterward, discuss the follow-up questions below.

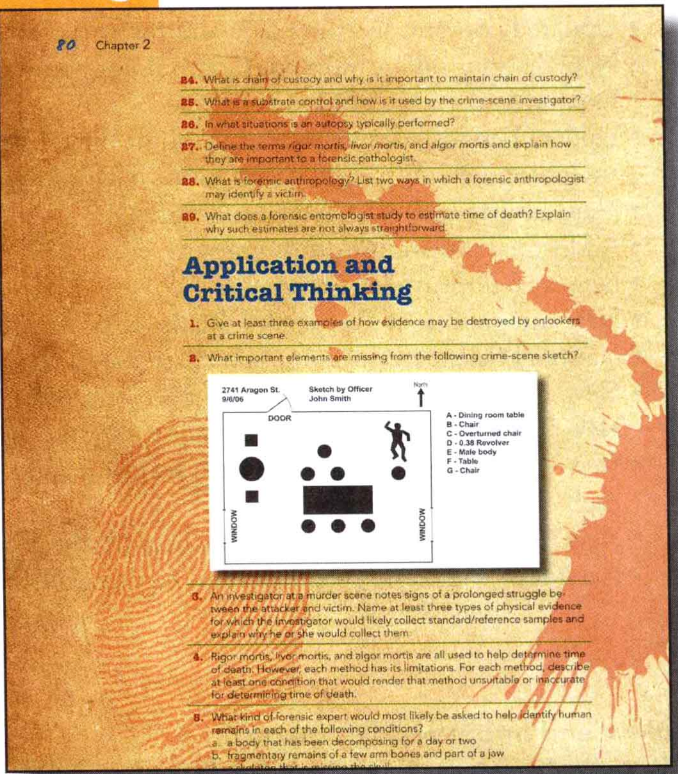
Follow-Up Questions:

1. Did any of your measurements match those of your partners? Were there any measurements for which several members of your group showed identical results? What might that suggest about the usefulness of that measurement for identification?
2. Compare all the measurements recorded for a single individual. Did every person who measured that individual obtain the same results? What factors may contribute to any differences in the results?
3. Do you believe that anthropometry would be a good way to identify people who are trying to hide their identity? Explain your answer.

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.



80 Chapter 2

24. What is chain of custody and why is it important to maintain chain of custody?

25. What is a substrate control and how is it used by the crime-scene investigator?

26. In what situations is an autopsy typically performed?

27. Define the terms *rigor mortis*, *livor mortis*, and *algor mortis* and explain how they are important to a forensic pathologist.

28. What is forensic anthropology? List two ways in which a forensic anthropologist may identify a victim.

29. What does a forensic entomologist study to estimate time of death? Explain why such estimates are not always straightforward.

Application and Critical Thinking

1. Give at least three examples of how evidence may be destroyed by onlookers at a crime scene.

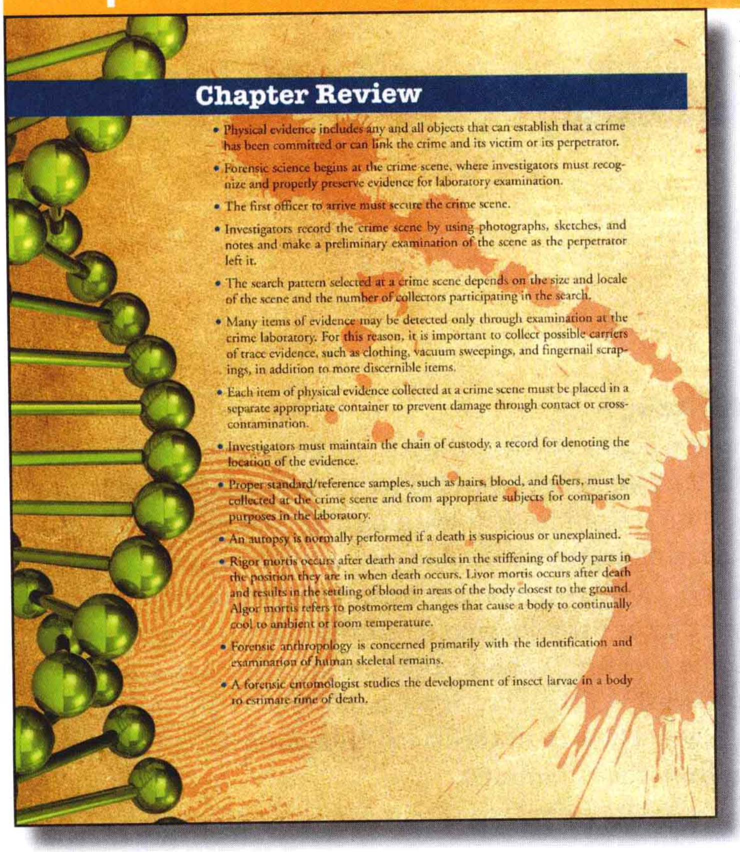
2. What important elements are missing from the following crime-scene sketch?

3. An investigator at a murder scene notes signs of a prolonged struggle between the attacker and victim. Name at least three types of physical evidence for which the investigator would likely collect standard/reference samples and explain why he or she would collect them.

4. Rigor mortis, livor mortis, and algor mortis are all used to help determine time of death. However, each method has its limitations. For each method, describe at least one condition that would render that method unsuitable or inaccurate for determining time of death.

5. What kind of forensic expert would most likely be asked to help identify human remains in each of the following conditions?
   a. a body that has been decomposing for a day or two
   b. fragmentary remains of a few arm bones and part of a jaw

Chapter Review and Assessment



Chapter Review

- Physical evidence includes any and all objects that can establish that a crime has been committed or can link the crime and its victim or its perpetrator.
- Forensic science begins at the crime scene, where investigators must recognize and properly preserve evidence for laboratory examination.
- The first officer to arrive must secure the crime scene.
- Investigators record the crime scene by using photographs, sketches, and notes and make a preliminary examination of the scene as the perpetrator left it.
- The search pattern selected at a crime scene depends on the size and locale of the scene and the number of collectors participating in the search.
- Many items of evidence may be detected only through examination at the crime laboratory. For this reason, it is important to collect possible carriers of trace evidence, such as clothing, vacuum sweepings, and fingernail scrapings, in addition to more discernible items.
- Each item of physical evidence collected at a crime scene must be placed in a separate appropriate container to prevent damage through contact or cross-contamination.
- Investigators must maintain the chain of custody, a record for denoting the location of the evidence.
- Proper standard/reference samples, such as hairs, blood, and fibers, must be collected at the crime scene and from appropriate subjects for comparison purposes in the laboratory.
- An autopsy is normally performed if a death is suspicious or unexplained.
- Rigor mortis occurs after death and results in the stiffening of body parts in the position they are in when death occurs. Livor mortis occurs after death and results in the settling of blood in areas of the body closest to the ground. Algor mortis refers to postmortem changes that cause a body to continually cool to ambient or room temperature.
- Forensic anthropology is concerned primarily with the identification and examination of human skeletal remains.
- A forensic entomologist studies the development of insect larvae in a body to estimate time of death.

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

New to This Edition

- Updated content on crime data and forensics technology throughout.
- New sections on anthropology, entomology, and odontology.
- Expanded coverage of blood spatter.
- Updated end-of-chapter questions to fit the needs and level of today's high school student, including new Application and Critical Thinking questions.
- New, briefer end-of-chapter summaries.
- Additional illustrations throughout.
- New and improved art program.
- New integration of Web-based media–MyCrime Kit and Virtual Labs.
- National Science Education Standards correlated to each chapter.
- New, enhanced, and current Case Files feature that links the content to real-world crime cases.
- New Inside the Science feature focuses the student on the science behind the topic.
- New Quick Review checks student learning and retention before getting too far ahead in each chapter.
- New Quick Lab features allow teachers to assign quick and easy lab exercises in the classroom with little prep time and easy-to-find supplies.

Student and Teacher Supplements

New and improved lab manual:
Basic Laboratory Exercises for Forensic Science (for purchase, ISBN: 013510534X)
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.

New to this edition:
Teacher's Wraparound Edition (ISBN: 0135089301)
The Teacher's Wraparound Edition features:

- Teacher's notes.
- Classroom management and planning tips.
- Lesson plans for customized instruction.
- Point-of-use teaching tips.
- Additional class and lab activities.

Companion Web Site (www.MyCrimeKit.com)

- Upon purchase students and teachers are given access to MyCrimeKit™. This site provides a broad range of materials, including book-specific learning objectives, chapter summaries, flashcards and practice tests, as well as video clips and activities to aid student learning and comprehension. Also included in MyCrimeKit are Research Navigator and weblinks that give students access to powerful and reliable research material. High school teachers can obtain teacher and student preview or adoption access for MyCrimeKit™ by either of the following means: Register online at **www.PearsonSchool.com/Access_ Request** (using Option 2) or ask your Pearson sales representative for an Access Code Card (Adoption Card 0-13-034391-9; Preview Card 0-13-111589-8).
- Also available are Virtual Forensic Science Labs. These multimedia lab animations allow students to walk through various lab exercises right from their computer.

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