Fundamentals of FORENSIC SCIENCE

Third Edition

MAX M. HOUCK AND JAY A. SIEGEL

Fundamentals of Forensic Science

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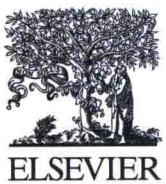

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Fundamentals of Forensic Science

To everyone who thinks impartial forensic science is necessary for justice. —MMH

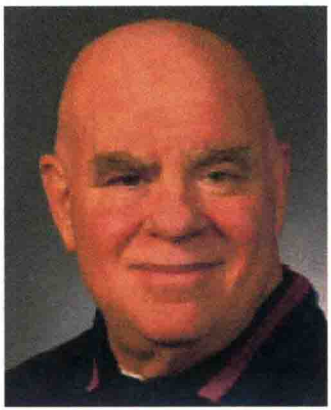
To Tommy and Ben – you are our legacy and our future and a source of great joy. —JAS

Editor: Biographies

MAX M. HOUCK

Dr Max M. Houck is an internationally recognized forensic expert who has worked in federal and local laboratories, the private sector, and academia. His casework includes the Branch Davidian Investigation, the September 11 attacks on the Pentagon, the D.B. Cooper case, and the West Memphis Three case, among hundreds of others. He serves on a variety of committees, including for Interpol. Dr Houck has published widely and is a founding Editor of the journal Forensic Science Policy and Management and has also co-authored numerous books. Dr Houck is a Fellow of the Royal Society of Chemistry.

JAY A. SIEGEL



Jay Siegel, PhD is retired director of the Forensic and Investigative Sciences Program and chair of the Department of Chemistry and Chemical Biology at Indiana University Purdue University Indianapolis. He was director of the Forensic Science Program at Michigan State University for 25 years from 1980 to 2004 until his retirement as Professor Emeritus. Dr Siegel is a Distinguished Member of the American Academy of Forensic Sciences and was named as Distinguished Alumni Scholar by his alma mater, George Washington University in 2011. He is co-editor of Forensic Science Policy and Management: An International Journal. He was a member of the National Academy of Sciences Forensic Science Committee from 2006 to 2009.

Foreword

Forensic science is at a transformational moment. The implications of the 2009 report from the National Academy of Sciences (NAS), *Strengthening Forensic Science in the United States: A Path Forward*, is finally being addressed, in part, by the formation of a National Commission on Forensic Science (NCFS) and the creation of Organization Scientific Area Committees (OSAC) overseen by the National Institute of Standards and Technology (NIST). The fundamental scientific basis that underlies many forensic disciplines is under review, and the role of "human factors"—issues of cognitive bias and laboratory organization—is now recognized to be of vital importance. However, what is not being addressed by either the Commission or the OSAC is the underlying validity (or lack thereof) of many impression, pattern, and trace evidence disciplines. Although NIST has agreed to validate and set measurement standards for a select subset of disciplines, it needs to do so for *all* the forensic disciplines it supervises in the OSAC structure. This gap is unfortunate since the absence of validation was an overarching concern of the 2009 NAS report. It makes little sense to assess the validity of some but not all, as *each* of the forensic disciplines is utilized in criminal investigations and adjudications affecting life and liberty.

The coauthors of this treatise, Max Houck and Jay Siegel, have been the central players in efforts to improve forensic science. They are not only thoughtful scholars in the academy but draw upon experience as bench scientists, laboratory managers, and, on occasion, expert witnesses. They wrote this extremely useful treatise to appeal to beginning forensic science students in college and high school (who have had some basic chemistry and biology) as well as a reference for science faculty and researchers as well as attorneys and judges.

Not only are the common forensic science topics (biology, chemistry, pattern evidence, law) covered but also the "ologies"—anthropology, entomology, and pathology. There are chapters on basic forensic science tools, spectroscopy, chromatography, and microscopy. There are also two new chapters in rapidly emerging fields: ethics for forensic service providers and computer forensics. In short, this is one stop shopping for those who are trying to get an introduction to the fundamentals of forensic science and its broad reach.

Most importantly, this book discusses some of the implications of the 2009 NAS report (Jay Siegel served on the NAS panel that wrote it and Max Houck testified twice before the Committee) throughout the text, especially in the controversial pattern evidence areas. There is also a new, extensive discussion of cognitive bias issues and its implications for forensic science. This includes an analysis of conformational bias in the famous Madrid Bombing case involving an erroneous fingerprint association led to the false arrest of Oregon lawyer Brandon Mayfield. Our only wish is that the authors would more directly take on all the too frequently exaggerated claims by forensic practitioners about the probative value of various forms of forensic evidence.

The book is both up to date and accessible to beginners. Each chapter begins with a real case as an illustration of the discipline at issue and revisits the case again at the end of the chapter. While acknowledging the continued popularity of forensic science in media (books, TV, and movies), this book will teach readers how forensic science is really practiced and what its real status is in court—no sugar coating or pandering to popular culture.

In his Foreword to the 2nd edition (Dwight Adams, retired FBI Laboratory Director) concluded by stating "This book, as its predecessor, will become a standard reference for those beginning their education in forensic science." We concur that the tradition continues!

Barry Scheck and Peter Neufeld
Cofounders and Codirectors of the Innocence Project

Preface to the Third Edition

We have written the 3rd edition of *Fundamentals of Forensic Science* because forensic science is once again at a crossroads with much at stake. Ever since commentators such as Saks and Kohler questioned the paradigm of individualization of scientific evidence, the pace of change and challenge has sped up. This was hastened by the landmark 2009 National Academy of Sciences report on forensic science, which acknowledged the strengths but demonstrated many weaknesses of the profession and the science. Since the NAS report came out, little has been accomplished until recently. The Departments of Justice and Commerce formed a National Commission on Forensic Science to help drive a national agenda on improving forensic science. The Commission, in turn, created an Organization of Scientific Advisory Committees, whose task is to develop consensus standards for the treatment of forensic evidence. Much hope is riding on these efforts to finally push for reform and garner resources to address the shortcomings of forensic science.

But that's not the most interesting part. The NAS report called for greatly increased research into the validity of forensic science methods of analysis. Research efforts have begun to accelerate in response. For example, preliminary research data show that fingerprint analysis, which has been undergoing increased scrutiny ever since the Madrid bombing case, has a false positive rate of 0.1% and a false negative rate of 7.5%. If letting a guilty person go free is better than convicting an innocent person that is good news indeed. Several studies in firearms, another discipline that has been increasingly challenged, have demonstrated overall error rates as low as 0.1% and only as high as 1.0% for false positives. Meanwhile, DNA analysis, the discipline that the NAS report called "the gold standard," is showing a mismatch between detection and interpretation. Numerous workshops held by the National Institute of Standards and Technology (NIST) have shown that forensic biologists using the same method for interpreting samples with more than one contributor (mixtures) get different answers—which are all potentially valid estimates of probability. No scientific or national standards exist for these methods. Forensic DNA is now in a position to detect more than it may be able to reliably interpret, which is troubling. Coupled with that is the next big shift in forensic DNA analysis, called next generation sequencing. That method is a few years off but it is coming and will utterly transform many aspects of the forensic profession, from technology to interpretation to privacy issues. When pattern evidence is proven reliable and DNA is beginning to be questioned, it is time to buckle up for a bumpy ride.

Other issues in the profession are looming. Lapses in integrity and the lack of an enforceable national code of ethics result in too many "forensic failure" headlines these days. And it is not only a few "bad apples," sometimes the entire crop is to blame. To stretch the metaphor, this brings the accountability and responsibility of the farmer (the manager or director) into question. Just about all cases of forensic science laboratory malfeasance demonstrate the importance of laboratory management and leadership. For example, Annie Dookhan, the drug analyst who lied about

her credentials and falsified evidence in hundreds of drug cases, has cost the state of Massachusetts $8.5 million in case reviews thus far and the state has budgeted another $8.6 million to complete the process. Dookhan is now serving 3–5 years in prison. It is easy to blame Dookhan for her crimes but what about laboratory management? Fellow employees complained about Dookhan's productivity, five times the normal average, even though they rarely saw her working at an instrument. Laboratory management praised Dookhan's work ethic and kept her on the bench. The search for solutions has to move beyond "blaming and shaming" individuals and toward a review of processes and systems and management.

Great gains often come with great pains and forensic science is no stranger to either. We have updated this edition to better reflect the changes that have occurred in forensic science since the 2nd edition and to anticipate some of the new trends on the horizon. Expanded discussion about policy, new methods, and new disciplines, such as digital evidence, demonstrate that forensic science is a dynamic field with great potential for progress and many issues to resolve. We hope you enjoy the 3rd edition of *Fundamentals of Forensic Science* and it helps you to understand this fascinating and engaging field of science.

MMH
JAS

Preface to the Second Edition

Much has happened in forensic science in the 3 years since the first edition of *Fundamentals of Forensic Science* was first published. The media are paying increasing attention to the accomplishments and problems in the field. The Madrid Bombing case highlighted the limitations of fingerprint science and the role of contextual bias in forensic science. Pattern evidence is increasingly being questioned in the courts. Forensic laboratories are working with public interest groups to test for DNA exonerations. The National Academy of Sciences released a long awaited report on the needs of forensic science that made 13 recommendations to improve the practice and development of forensic science. The number of forensic science degree programs in the United States continues to increase at both the BS and MS levels. The Forensic Science Education Program Accreditation Commission (FEPAC) is in full swing and has accredited over 26 forensic science degree programs. Science continues to progress in the areas of materials science, microfluidics, nanotechnology, and fundamental discoveries. We indicated in the preface to the first edition of *Fundamentals* that forensic science education was entering an exciting era. We reiterate that now but with greater emphasis. The field faces great challenges, not the least of which is a seemingly insurmountable backlog of cases, caused in part by an insufficient number of forensic scientists. Joseph Peterson, in his 2005 *Census of Public Crime Laboratories*, estimated that it would take more than 1900 new forensic scientists to get the nationwide case turnaround time to 30 days. This means that forensic science education programs must be able to produce quality science students. The other side of this yet-to-be-balanced equation is that the laboratories must be able to hire, train, and manage all these new scientists.

We wrote *Fundamentals of Forensic Science* to provide a realistic view of the field of forensic science from the viewpoint of the forensic scientist—both of us have been and continue to be active as practitioners in the field. As current academics, we know this book must convey how forensic science is done in the field, in the laboratory, and in the courtroom, otherwise it has little legitimacy. Our philosophy hasn't changed and the second edition of *Fundamentals* reflects that. We have kept the same chapter structure in the same order: Forensic science is presented from crime scene to courtroom. We offer foundational material in the beginning; crime scene, evidence, and the tools of the laboratory; microscopy, separation science, and spectroscopy. We then present many of the most common and not so common types of forensic evidence collected by the types of science that are employed in their analysis; physical, chemical, and biological. The "-ologies": pathology, entomology, odontology, and anthropology are still there. The book is designed to be used in a one-semester or two-semester format and is suitable for any student who has a basic science background. To us, this reflects where forensic science must, as a discipline, stand shoulder-to-shoulder with its peer sciences.

Fundamentals is also "new and improved." Most of the chapters begin with a discussion of real cases in that area and they are referred to throughout the chapter. Other real cases are also discussed throughout the chapters, albeit in encapsulated form. In place of the key words at the beginning of each chapter, terms are now defined as they come up within the chapter, reinforcing the concept while you are still reading. All of the materials have been updated; some new materials were added where they were needed and we upgraded figures and added some new ones. The bottom line: we have taken a good thing and made it better. We hope that you will agree.

MMH
JAS

Preface to the First Edition

Fundamentals of Forensic Science represents a different, albeit more realistic, view of the field of forensic science than is found in other textbooks. This view includes areas that are central to criminal investigations but fall outside the typical definition of "criminalistics." From the beginning, we decided to make *Fundamentals of Forensic Science* reflect how professional forensic scientists work and not how forensic science academicians teach. This enabled us to include the "-ologies" (pathology, entomology, anthropology, etc.) that many instructors don't traditionally teach—but that's probably because the chapters don't exist in other books. We felt that many instructors would like to teach these topics but don't have the fundamental resource materials to do so; additionally, students may want to read about a discipline that interests them but isn't covered in the course. The instructor may have local experts lecture on these specialties but, without these chapters, the students don't have any foundation to appreciate what the expert presents. If the instructor uses a video of a case, in the absence of a local expert, the students can be even more lost—the application of the methods in the case are key and the background information may be glossed over. In this regard, *Fundamentals of Forensic Science* provides the basis for the integration of these critical topics into the overall course. Our hope is that *Fundamentals of Forensic Science* fills this need.

We also offer a new perspective on the nature of forensic evidence. In his *Science* article, "Criminalistics" from 1963, Kirk opines that the principles that bind the various disciplines into the whole of forensic science "center on identification and individualization of persons and of physical objects." But this is only part of the larger nature of the discipline: The binding principles relate to relationships between people, places, and things as demonstrated by transferred evidence. It doesn't matter so much that this ceramic shard came from a particular lamp—it *does* matter, however, that the shard was found in the dead person's head and the suspect's fingerprints are found on the lamp. It is not merely the identification or individualization of the objects but it is the *context* of those people, places, and things and their relationship or interrelatedness within that context that provides its value in the justice system. A crime scene is a set of spatial relationships and/or properties; all evidence is spatial in that sense. Even an item of evidence discarded a distance from the scene by the perpetrator has meaning. A crime scene can also be viewed as a piece of recent history. It has a story to tell and the various pieces of evidence carry the facts of the story within them. In that sense, forensic scientists are auditors and storytellers.

In *Fundamentals of Forensic Science*, we stress these associations and how they relate the evidence to the facts of the crime. We also emphasize that *all* evidence is *transfer* evidence (à la Locard), even evidence that may not have been characterized as such, like DNA (semen transferred by sexual contact in a sexual assault), pathology (the pattern of a weapon transferred and recorded in the wound of a victim), or entomology (the number and kinds of maggots that have accumulated—transferred from the environment—on a decomposing body). Locard's Exchange Principle,

then, is *the* binding principle in forensic science because it focuses on reconstructing relationships in the commission of a crime through the analysis of transferred information.

Forensic science education is entering an exciting era, ushered in largely by the work of the Technical Working Group on Education and Training in Forensic Science (TWGED). This group, sponsored by the National Institute of Justice (NIJ) and West Virginia University, generated guidelines for building careers in forensic science, curricula for undergraduates and graduates, and continuing education for professional forensic scientists. These guidelines led the American Academy of Forensic Sciences (AAFS) to form the Forensic Education Program Accrediting Commission (FEPAC), an accrediting body for forensic science educational programs. New forensic science educational programs appear weekly, it seems, and, because the quality of education goes to the heart of any profession, standards are a necessary component to assure that they prepare students properly for careers in our field.

The teaching of forensic science has spread from graduate and 4-year programs to community colleges and high schools. While writing a book targeted for one end of that spectrum most likely makes it unsuitable for the other end, we see *Fundamentals of Forensic Science* as being appropriate across that spectrum. Educators teaching a forensic science course for the first time will find the supplemental course materials helpful in getting started. Experienced educators will find these resources helpful as well but will also appreciate the breadth and depth of the chapters of this text. Despite its broad applicability, our intent in writing *Fundamentals of Forensic Science* was for students who have already taken basic science courses.

Fundamentals of Forensic Science is organized roughly along the timeline of a real case. It begins with an introduction and history of forensic science as background to the discipline and the structure of a modern forensic science laboratory. Chapter 2 covers the processing of crime scenes and Chapter 3 covers the nature of forensic evidence. In Chapters 4 (Microscopy), 5 (Spectroscopy), and 6 (Chromatography), we cover the basic methods of analysis used in most, if not all, forensic science examinations. The biological sciences are then presented: Pathology (Chapter 7), anthropology, and odontology (Chapter 8), entomology (Chapter 9), serology and blood pattern analysis (Chapter 10), DNA (Chapter 11), and finally hairs (Chapter 12). The next chapters address the chemical sciences, drugs (Chapter 13), toxicology (Chapter 14), fibers (Chapter 15), paints (Chapter 16), soils and glass (Chapter 17), and arson/explosives (Chapter 18). The third section covers physical evidence, including friction ridges (Chapter 19), questioned documents (Chapter 20), firearms and toolmarks (Chapter 21), shoeprints, tire treads, and other impression evidence (Chapter 22). The final chapter in the book looks at the intersection of forensic science and the law (Chapter 23).

Feature boxes throughout the book emphasize resources on the World Wide Web ("On the Web"), historical events in forensic science ("History"), practical issues in laboratory analysis ("In the Lab") and topics for further reading or interest ("In More Detail"). Each chapter ends with two types of questions to help with chapter review and discussion: "Test Your Knowledge" questions target key terms and

information from the chapters while the questions under "Consider This..." offer topics and issues that should challenge the students knowledge and understanding of the chapter contents.

With a project like writing a textbook (we submit that *no* project is like writing a textbook!), compromises must invariably take place. Our aim was to yield only where necessary and to dig in when we felt our vision of the book was in jeopardy. We feel that the decisions we made have resulted in a better product and hope that you do as well.

MMH
JAS

Acknowledgments

The authors would like to thank everyone who offered suggestions, comments, criticism, and ideas for this textbook: Without you, it would not be the quality text that it is.

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