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Forensic Science
An Introduction to Criminalistics

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FORENSIC SCIENCE

AN INTRODUCTION TO CRIMINALISTICS

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PREFACE

Forensic science has emerged as a significant element in efforts to control crime while maintaining a high quality of justice. The value of physical evidence and its analysis has been demonstrated in many ways on many occasions, and law enforcement officials have become increasingly dependent on laboratory results for evidence not obtainable by other avenues or means of investigation. As science and technology continue to advance, the capabilities and importance of forensic science laboratories will also continue to grow. At present, all fifty states, and many individual cities, towns, and counties, have forensic science laboratories serving them. Many communities without laboratories are exploring ways to develop and staff them, and those that already have laboratories are looking into ways to improve them and increase their level of services.

Forensic Science: An Introduction to Criminalistics was written as a basic textbook for use in college and university forensic science courses at the introductory level. Little or no prior knowledge of science has been assumed. Enough background material is given in each chapter to enable the student to understand and appreciate the laboratory procedures, their underlying principles, and their potential value and limitations.

This book is suitable for any one-semester introductory course in forensic science for police officers, crime-scene investigators, or beginning students in law enforcement, criminal justice, or forensic science. Other criminal-justice practitioners, such as attorneys or judges involved in criminal cases, may also profit from the information contained in these pages.

Although most of the chapters are devoted to particular kinds of physical evidence, we have taken some care to explore different conceptual ways of looking at various classes of physical evidence. Two types of evidence might be very different in nature, for example, but the methods of analyzing them may have a great deal in common or may even be identical. Similarly, various types of patterns are analyzed and interpreted primarily as an aid to the reconstruction of events, although the patterns may have been produced by quite different events involving quite different materials.

Although we have not formally divided the book into sections, many of the chapters may be grouped. The first three chapters are devoted to introductory, conceptual, and background material and to some basic scientific concepts and the methods that are used in examining physical evidence. Subsequent chapters, which deal with methods, techniques, and approaches, contain back-references to the descriptions of the methods. In this way, students can refer back to the appropriate introductory section as necessary. Chapters 4 and 5 cover most of the types of evidence that require chemical analysis primarily, namely, evidence from suspicious fires and explosion cases, and drug and toxicological materials. Chapters 6 through 10 discuss trace and transfer evidence. Those types of evidence that do not need a full chapter of their own are discussed in Chapter 6. Chapters 9 and 10 have to do with forensic serology. Chapters 11 through 14 follow a logic similar to that of Chapters 6 through 10, except that the subject matter is physical pattern evidence. Throughout, we have tried to stress the fundamental concepts of identification, individualization, and reconstruction in the chapters on particular evidence types. Some material and information that is more technically complex than seemed to be warranted in the main text has been included in certain figures and tables for interested readers. The essential points made in the chapters, however, will not be diminished if this material is not covered or studied in great detail.

Another relationship we have tried to develop is the one between the crime scene and the laboratory—between crime-scene investigators and laboratory examiners. Collection, preservation, and packaging of evidence at a crime scene are discussed generally and for each of the different types of evidence.

Likewise, methods of analysis for each type of evidence are discussed in some detail. There seems to be little doubt that crime-scene searches will be carried out more thoroughly and skillfully, and evidence packaged and preserved properly, if investigative officers understand and appreciate what kinds of analyses can be done. The effect of collection and preservation methods on the results that can ultimately be obtained must be understood by crime-scene personnel as well as by laboratory examiners. Recognition, documentation, handling, packaging, and analysis of physical evidence are all parts of a coherent, continuous process that, taken together, make up the overall forensic analysis.

The three appendixes treat topics that are largely self-contained but whose subject matter occurs in a number of different places in the various chapters. Appendix 1 covers basic scientific measurements and the metric system. Appendix 2 is a discussion of crime-scene procedures. It is intended to supplement the material presented elsewhere in the text on specific evidence types and situations, and tie it together conceptually. Instructors wishing to include lessons on photography in their courses can treat Appendix 3 as a chapter. It can be taken up at any point following the study of Chapter 3. Appendix 3 is designed as an aid in acquiring an understanding of fundamental photographic theory and principles rather than being a "how to" treatment of photography. Practical details of specific techniques, methods required by particular cameras, films, and processes as well as "tricks of the trade" can be supplied by the instructor and reinforced by supplemental reading assigned by the instructor. The list of references included at the end of the appendix should prove helpful in making these assignments.

Throughout the book we have tried to illustrate certain specific and general points about forensic science and physical evidence by including descriptions of real-world cases. Some of these are well known, and others come from our collective experience or that of our colleagues and friends.

We hope that these pages will convey some of the excitement about and enthusiasm for our work that the practice and teaching of forensic science have brought us and that we trust some of our readers may share.

The mention of specific products and brand names and the products of specific companies is for information and illustration purposes only; it does not constitute an endorsement of any specific item or product by the authors or by the publishers.

A number of people have assisted us in various ways in the long and sometimes arduous task of preparing this book, and it is with pleasure and gratitude that we acknowledge their assistance and support: Julie K. Bremser, Elaine M. Pagliaro, James J. Horan, Francis X. Sheehan, Philip C. Langellotti, W. Reid Lindsay, Robert A. Hathaway, Marshall Robinson, Marius Venclauskas, and James Behrendt were all extremely helpful in reading and commenting upon the material in its earlier stages of preparation. In this respect, we wish to add a special note of appreciation to Professors W. Jack Cadman, Michael J. Camp, Richard W. Chang, Joseph L. Peterson, and George W. Roche. Doctors Richard Pinder and Joseph Balkon were extremely helpful to us in the preparation of the chapter on drug analysis and forensic toxicology.

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Peter R. De Forest
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CONTENTS

CHAPTER 1

ABOUT FORENSIC SCIENCE

SCIENCE AND LAW

Forensic science is the application of the natural sciences to matters of the law; it includes a variety of different activities and specialties. In practice, forensic science draws upon the principles and methods of all the traditional sciences, such as physics, chemistry, and biology. At the same time, there are differences between forensic science and traditional sciences. The differences are attributable in part to the fact that forensic science has some unique objectives, and in part to its continuous and necessary interaction with the legal system.

Natural Sciences and the Scientific Method

Science is not easy to define simply. Popular perceptions of what science is, and what scientists do, are often inaccurate. Many people think of scientists as people who use complex (even secret) means that nonscientists do not understand to gain knowledge that will benefit humanity. Another misconception is that scientific results or conclusions represent "absolute truth." If a result or conclusion is "scientific," people are conditioned to believe that it must, therefore, be right. Advertising techniques commonly attempt to exploit this belief.

Although the attainment of "truth" is one of the goals of science, and thus one of the bases for using the so-called scientific method, this ideal is not achieved in actual practice. Actually, science is that area of human endeavor which tries to organize and understand the connections among natural phenomena. Science is concerned only with *natural* phenomena, with things and processes that are subject to observation, measurement, and experimentation. In addition, science can be distinguished from other disciplines on the basis of its combined theoretical and empirical approach, which is usually called the *scientific method.*

The scientific method may be characterized as consisting of several more or less separate steps: observation (collection of data), conjecture, hypothesis, testing, and theory. Most scientists do follow this general procedure without really thinking about it. Observations are made and data collected. The significance of the observations is considered (conjecture), until some reasonable explanation consistent with all the data—a hypothesis—is arrived at. Experiments designed to test the hypothesis are then conceived and carried out. The new data thus obtained are used to refine the initial hypothesis as necessary. A modified hypothesis which has been verified by a good deal of rigorous testing may come to be called a *theory.* Sometimes, theories which have been extensively tested and verified by many scientists working independently may come to be regarded as *natural laws.*

Forensic scientists engaged in reconstruction of events follow the essential principles of the scientific method just outlined. In attempting to reconstruct the events which took place at a crime scene, for example, the first step is careful observation and assembly of all the known facts. Different hypotheses can then be entertained to see how well one or another of them corresponds to all the facts. As additional facts are disclosed by further observation or by experimental testing, it may be possible to arrive at a theory of what took place.

The scientific method is not some strict set of rules by which all scientists proceed. Rather, it is a particular way of going about gathering information about the natural world and of attempting to organize and understand it. Elements of both deductive and inductive logic are used in applying the scientific method.

In *deductive logic,* a conclusion follows inescapably from one or more of the premises. If the premises are true, then the conclusion drawn is valid. Consider the following example of deductive logic. The oxygen carrier and red pigment in the blood of all mammals is hemoglobin. Human beings are mammals; therefore, human blood contains hemoglobin. The conclusion here is a logical consequence of the two premises. Mathematical proofs are examples of deductive logic. The conclusion is based on the facts in the premises.

In the experimental sciences, deductive logic alone would not be adequate. It is often necessary to go beyond the facts, and to draw conclusions that may have predictive value. This type of reasoning is known as *inductive logic,* and leads to the development of hypotheses. The conclusion drawn has not been proved to be true, although in some cases it may be regarded as being true from a practical point of view. A conclusion may be based on such a vast amount of experience that it is unlikely to be false. We have arrived at the conclusion, for example, that fingerprints are individual, but this has never been rigorously proved. The conclusion is reached through inductive logic, and is based upon millions of observations. The reasoning behind the conclusion runs as follows: Tens of millions of fingerprints have been catalogued in national files. Thus far no two people have been found to have the same fingerprints; therefore, fingerprints are (probably) individual. In order to prove this conclusion rigorously, by deductive logic, it would be necessary to compare the fingerprints of every person living on earth! If two sets were found which matched, then the conclusion arrived at inductively would be false. Since it would be impossible to conduct the examination of every person's fingerprints, we must be satisfied with the conclusion arrived at inductively, by extrapolation from limited experience with a few million examples thought to be representative. Even though the inductive conclusion has not been rigorously proved, it seems quite unlikely that it is false. It is, therefore, a probable conclusion. Such conclusions may be drawn from analogies or informed conjecture that is based upon a large amount of representative data. To be useful at a practical level, it is necessary only that they prove to be correct most of the time.

In summary, then, science begins simply with curiosity about some natural phenomenon. A scientist then makes observations on the phenomenon and formulates an "educated guess" to explain the observations. This guess is the *hypothesis*. Since the hypothesis represents an explanation of some phenomenon, it is possible to make some predictions based upon it. In order to be within the realm of science, a hypothesis must be able to generate predictions which are *experimentally testable.* Hypotheses or theories which are not subject to experimental testing are outside the realm of science. Scientific hypotheses are tested by determining experimentally the truth of their predictions. True hypotheses always yield true predictions. The trouble is that false hypotheses can also yield true predictions, as well as false ones. Thus, experiments which show that a prediction is true do not necessarily demonstrate that the hypothesis from which the prediction was derived is true. They merely lend support to the hypothesis.

The experiments which scientists conduct to test hypotheses are designed to be *controlled,* so that there is only one variable at a time. In practice, it is not usually possible to construct experiments with absolute certainty that only one parameter is variable. Unrecognized variables may influence experimental results. As many different experiments are conducted on a particular question, however, the truth or falsity of a hypothesis becomes clearer, since many different predictions are tested over the course of time. If a hypothesis leads to a prediction that is shown experimentally to be false, the hypothesis has to be changed. Hypotheses are thus altered over the course of time as more and more experiments are conducted to test their validity. As they are modified and altered, hypotheses get closer and closer to "the truth." Because of this self-testing and experimental nature, scientific knowledge is always changing. There is no guarantee that yesterday's truth will be the same as tomorrow's. A hypothesis which has been extensively tested, and which generates a large number of true predictions, is often called a *theory*. The body of scientific knowledge that exists at any given time represents the best explanation of natural phenomena which has been formulated up to that time. It is not possible to know how close to the "real truth" scientific knowledge is at any particular time. The history of science has taught us to be skeptical about what we think is true.

Law and Legal Systems

From ancient times, recorded history has been filled with accounts of different codes, or laws. People trying to live together and function harmoniously in an organized society have always tried to regulate their affairs and relationships in some systematic way. Codes are designed to provide an orderly basis for the conduct of human affairs. Some laws and legal systems have a religious basis; others are purely secular. Legal systems operate under many different forms of government. The laws in effect at any given time are usually influenced by or derived from those of previous periods.

Various activities, regarded as contrary to the collective interest or to some generally accepted moral code, are forbidden by laws. The existing authority then provides for sanctions against those who engage in the forbidden activities. The activities involving relationships among people are also subject to certain rules. In a general way, *criminal* codes govern activities in which society as a whole has an interest, and *civil* codes tend to govern relations between individuals or groups. The distinction between criminal and civil matters depends on the social and historical context of the society which created the laws. Legal structures are always reflections of particular societies at particular times. Without exception, however, the dynamics of their operation represent a human activity that depends on decision making. Legal decision making is nearly always vested in some kind of court or tribunal. Codes and legal systems cannot anticipate every possible circumstance under which disputes will arise between people or with the state. The function of the courts or tribunals, therefore, is to make reasoned judgments in particular cases. They try to apply the general principles of the legal code to the particular circumstances of a given situation. To exercise their function responsibly, courts have always sought ways to ascertain the facts surrounding particular cases. The relationship between law and science had developed out of a common interest in factual information. Although the concepts of *scientific fact* and *legal fact* are often quite different, the application of scientific methods can often provide factual information that is relevant to a legal proceeding and would not be available without the intervention of science.

SCOPE OF FORENSIC SCIENCE

The term *forensic science* is sometimes used as a synonym for *criminalistics*. Both terms encompass a diverse range of activities. Forensic science is also defined in a broader sense to include forensic medicine, odontology, anthropology, psychiatry, toxicology, questioned documents examination, and firearm, toolmark, and fingerprint examinations, as well as criminalistics.

Criminalistics is concerned with the recognition, identification, individualization, and evaluation of physical evidence using the methods of the natural sciences in matters of legal significance. It includes all the areas of trace-evidence examination and forensic chemistry. It also includes the reconstruction of events based on physical-evidence analysis. Different forensic scientists would define the scope of the field differently. Some would include firearm and toolmark examination and questioned documents as a part of criminalistics, for example. Despite the implications of the name, criminalistics activities are not limited to criminal matters. They are used in civil law cases and in regulatory matters as well. People who are engaged in criminalistics as a profession are called *criminalists*.

The major specialty areas included in the wider definition of forensic science are described briefly below. Some of them are taken up in more detail in later chapters.

Forensic medicine (legal medicine; medical jurisprudence) is the application of medicine and medical science to legal problems. Practitioners of forensic medicine are doctors of medicine with specialty certification in pathology and forensic pathology. Most of them are medical examiners. They are concerned with determining the cause and circumstances in cases of questioned death. They also become involved in matters having to do with insurance claims, and sometimes in cases of medical malpractice.

Forensic odontology (forensic dentistry) is the application of dentistry to human identification problems. Forensic odontologists are dentists who specialize in the forensic aspects of their field. They are concerned with the identification of persons based upon their dentition, usually in cases of otherwise unrecognizable bodies or in mass disasters. They also analyze and compare bitemark evidence in many types of cases.

Forensic anthropology has to do with personal identification based on bodily (particularly skeletal) remains. Practitioners are physical anthropologists who are interested in forensic problems. Other areas of forensic anthropology include establishing data bases on bodily structures as functions of sex, age, race, stature, and so forth. Interpretation of footprint or shoe-print evidence might also be included.

Forensic toxicology has to do with the determination of toxic substances in human tissues and organs. Much of the work concerns the role toxic agents may have played in causing or contributing to the death of a person. Further discussion is found in Chapter 5.

Criminalistics includes all the areas of trace and transfer evidence (Chapter 6), such as glass and soil (Chapter 7), fibers and hairs (Chapter 8), blood (Chapter 9), and physiological fluids (Chapter 10). It also includes arson accelerant and explosive residues (Chapter 4), drug identification (Chapter 5) and the interpretation of different patterns and imprints (Chapter 11). It is the broadest of the subdivisions of forensic science.

Questioned documents examination includes comparisons and interpretation of handwriting, mechanically produced material (typing, printing), and photocopied material. Analysis of papers, inks, and other materials used to produce documents may also be included. This subject is covered in Chapter 13.

Firearm and toolmark examination has to do with firearm identification, comparison of markings on bullets and other projectiles, cartridge cases, and shell cases, especially for the purpose of determining that a bullet may have been fired from a particular weapon. Toolmark examinations are concerned with the association of particular impressions with particular tools. A detailed discussion is given in Chapter 14.

Fingerprint examination is concerned with the classification of fingerprints and the organization of sets of prints into usable files. Development of latent prints and comparisons of known and unknown fingerprints are a part of the work as well. This material is discussed in Chapter 12.

Some forensic science activities can be classified under more than one of the major subdivisions above. Toolmark comparisons, for example, are sometimes considered part of criminalistics and sometimes as part of the separate *firearms and toolmarks* specialty. Similarly, hair comparison is usually considered a part of criminalistics, but it could just as well be considered a part of forensic anthropology. Any classification scheme for all the different activities is, therefore, somewhat arbitrary. No one person can be expert in all the sciences and their methods, and it is for this reason that forensic science contains subspecialties. The subspecialties develop around a particular type of physical evidence, or around a particular group of methods and procedures. Some forensic scientists are generalists. They have broad training and experience in most of the basic areas of criminalistics, can carry out a variety of different physical-evidence examinations knowledgeably, or more importantly, refer specific aspects of a case to specialists.

This book is concerned primarily with criminalistics, and the emphasis is on criminal-case applications.

The range of human activity is so diverse that almost anything can become *physical evidence* under one circumstance or another. In any criminal, civil, or regulatory matter, there can be physical evidence which, if recognized, properly handled, and knowledgeably interpreted, can contribute importantly to an understanding of the case.

The methods used in forensic science are those of traditional scientific disciplines, like chemistry, biology, physics, geology, or medicine; but forensic science is something more than a "patchwork quilt" of various disciplines and methods. Before any traditional scientific work is done at all, a forensic scientist or investigator must *recognize* physical evidence in a particular case. Something that is extremely important in one case might be part of the background in another one. A forensic scientist must also be able to decide what kinds of tests, measurements, or analyses on a piece of evidence will be informative under the particular circumstances. And, unlike traditional scientists, a forensic scientist has no control over the condition or history of an item of physical evidence. In many cases, the history of the item is unknown.

The dimensions of a forensic science investigation may include any or all of three major activities in analyzing and interpreting physical evidence: (1) identification, (2) individualization, and (3) reconstruction.

Identification is a process common to all the sciences and, in fact, to everyday life. It may be regarded as a classification scheme, in which items are assigned to categories containing like items, and given names. Different items within a given category all have the same generic name. In this way, botanists will identify plants by categorizing and naming them. Likewise, chemists identify chemical compounds. In forensic science, identification usually means the identification of items of physical evidence. Some types of physical evidence require that scientific tests be conducted to identify them. Drugs, arson accelerants, bloodstains, and seminal stains are examples. Objects are identified by comparing their *class characteristics* with those of known standards or previously established criteria. Class characteristics are the properties that all the members of a certain class of objects or substances have in common.