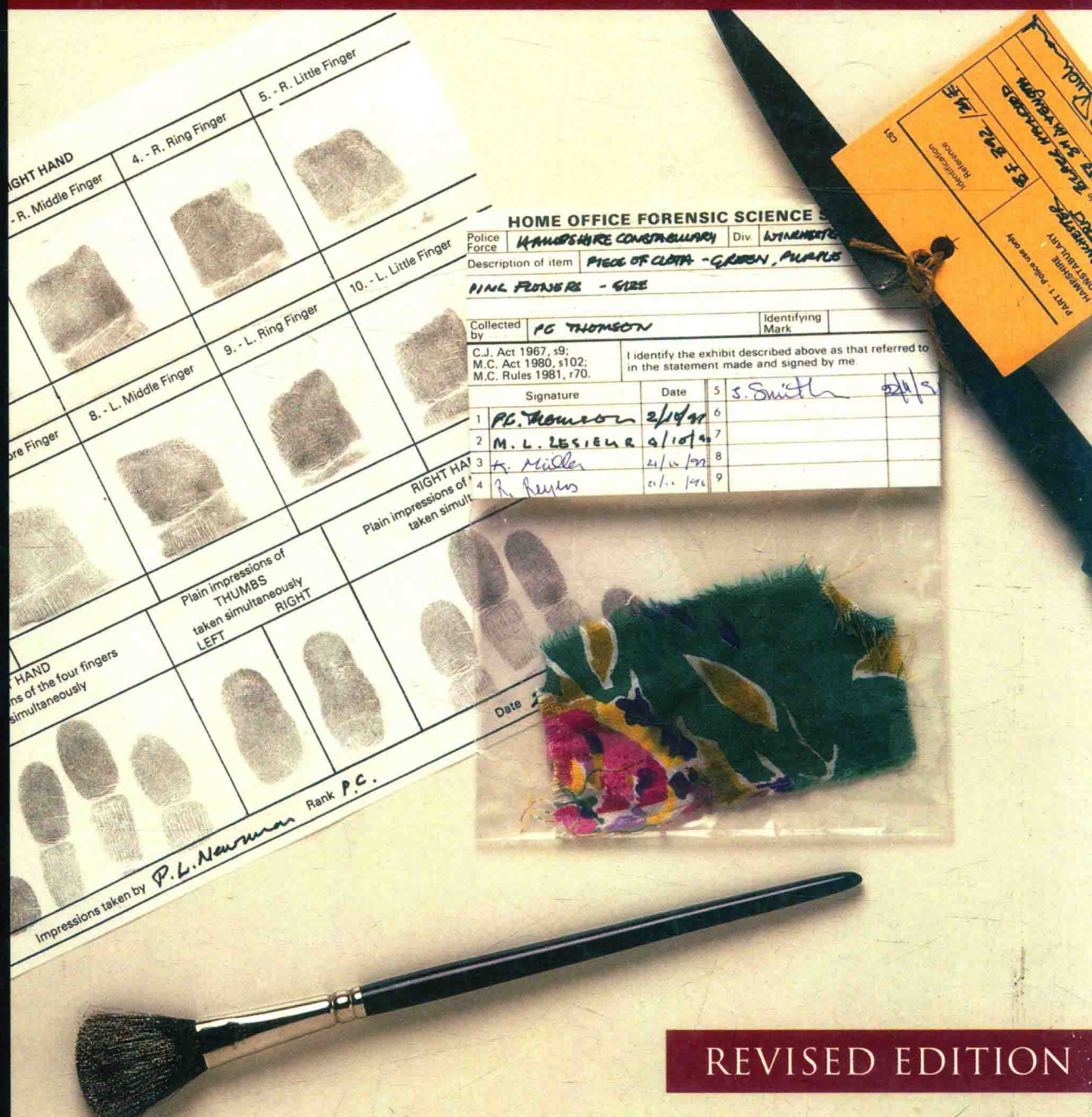




ENCYCLOPEDIA OF FORENSIC SCIENCE

SUZANNE BELL, PH.D.



REVISED EDITION

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REVISED EDITION

SUZANNE BELL, PH.D.

BENNETT DEPARTMENT OF CHEMISTRY,
WEST VIRGINIA UNIVERSITY, MORGANTOWN

FOREWORD BY

BARRY A. J. FISHER

AMERICAN ACADEMY OF FORENSIC SCIENCES,
PAST PRESIDENT, 1998-1999
CRIME LABORATORY DIRECTOR,
LOS ANGELES COUNTY SHERIFF'S DEPARTMENT

PREFACE BY

ROBERT C. SHALER, PH.D.

DIRECTOR, FORENSIC SCIENCE PROGRAM,
PENNSYLVANIA STATE UNIVERSITY

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Encyclopedia of Forensic Science, Revised Edition

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*To my husband, Mike, and to my departed mother—
thanks for all the years of faith and support.*

FOREWORD

Hardly a week passes when I do not receive a phone call or e-mail from a college or high school student asking about careers in forensic science or wishing to interview someone for a class report they must do on forensic science. To be sure, much of this interest is a result of nearly a decade of media hype from such television programs as *CSI*, *Forensic Files*, and dating all the way back to the O. J. Simpson trial coverage. But for whatever reason, there is a genuine fascination about the subject. What is forensic science? What sort of academic preparation do I need to enter this field? Where do I turn for answers?

Crime laboratories and medical examiner/coroner's offices play a vital role in our nation's criminal justice system. Forensic science brings science, medicine, and technology to bear in criminal investigations and helps police and prosecutors do their jobs better. Those who work in this field have university degrees in chemistry, biology, and the like.

Suzanne Bell's *Encyclopedia of Forensic Science, Revised Edition*, an excellent reference, again addresses many of the questions people have who are considering careers in this field. The encyclopedia is also a wonderful resource for the general public who is simply interested in the subject matter. Arranged as a collection of literate entries enhanced by 14 relevant essays, Bell covers the expansive area of forensic science well. She provides readers interested in forensic science with a single source that is easy to understand, accessible, and very well written.

The book is organized in alphabetical order—A through Z—whereas entries and their cross-references that have to do with the subject are easily found and explained along with essays on a number of subject areas. She has also done a fine job in bringing the volume up to date with both new and revised entries to be as complete a reference as possible.

For those seriously considering forensic science as a career, I also recommend one of the many fine professional organizations in the area. Membership information is easily found on the Web. Three of the many fine organizations are the American Academy of Forensic Sciences, the International Association for Identification, and the National Association of Medical Examiners. These are but a few of the other resources available.

Professor Bell's *Encyclopedia of Forensic Science, Revised Edition* is an excellent start to begin your exploration of this intriguing field of study.

—Barry A. J. Fisher

American Academy of Forensic Sciences President, 1998–1999

Crime Laboratory Directory Director

Los Angeles County Sheriff's Department

PREFACE

Young students nationwide are increasingly attracted to what might arguably be the “new wave” profession: forensic science. Whether this interest stems from the plethora of television shows, such as the numerous documentaries and docudramas currently broadcast, or from an inherent interest in forensics, students are flocking to the profession in unprecedented numbers. Universities offering forensic science degrees are springing up throughout the country to meet the demand, and high school science teachers are adding forensic courses to their science curricula. Forensic science touches the everyday world in multiple ways, so it stimulates impressionable young minds and propels students toward careers in forensic-related professions: law enforcement, the law, medicine, nursing, and science.

Re-creations of the practice of forensic science on television programs such as *C.S.I.* and *Forensic Files* also affect events in the real world. For example, jurors are demanding more science in the courtroom, a phenomenon known as the C.S.I. effect, which forces prosecutors and defense attorneys to consider how the science will affect their cases when going to trial. Law-enforcement and legal officials working in the criminal justice system are subjected to forensic practice almost daily, and many struggle to understand the science of forensics without having a scientific background.

Thus, many individuals and organizations in our complex modern society, because of an interest in forensics, career aspirations, or professional practice need an authoritative source of forensic information. Certainly many forensic-science textbooks are readily available, but these are mostly written for practicing professionals or college-level students and do not consider the nonscientist. Such a resource should be written by a forensic scientist, an educator who understands the nuances of forensic practice, its legal implications, and relationship to our criminal justice system. The resource must be comprehensive and explain the science behind forensic practice accurately but at a level that a nonscientist easily comprehends.

Suzanne Bell’s *Encyclopedia of Forensic Science, Revised Edition* is such a resource: It is a comprehensive, factual reference for anyone interested in learning about topics in forensic science from a lay perspective. Like any encyclopedia, the book lists subjects alphabetically, is extensively cross-referenced, and provides references for further reading. For example, Bell cross-references “shotguns” under “firearms,” where she writes about various types of firearms and includes a history of firearms. Under “FBI,” she gives a brief history of the agency. In another section she discusses how the scientific method relates to forensic scientific investigations.

The book also includes helpful “Feature Essays,” sprinkled throughout the encyclopedia, that illustrate how contemporary topics—drugs, fingerprinting, sports, etc.—relate to forensic science. Dr. Bell pulls no punches when candidly discussing confounding issues in modern forensic science, such as ethics, bias, and individualization versus identity.

An interesting aspect of the encyclopedia is her treatment of historically famous cases. In the Lindbergh kidnapping and murder case of the 1930s, for example, she explains how questioned documents and tool-mark examinations helped to prove Bruno Hauptmann’s guilt. In the Sam Sheppard murder case of the 1950s, Bell explains why Dr. Paul Kirk believed Sheppard was innocent, based on bloodstain patterns he analyzed at the crime scene. She mentions the pioneers of forensic science in the encyclopedia and the role they played in shaping contemporary forensic science. She dives into the influence of recent court decisions, such as the Daubert decision in 1993 that defined the admissibility of scientific evidence in federal courts.

In an era where the word *forensic* seems ubiquitous and most every profession has or wants a “forensic” bent—forensic meteorologists, veterinarians, kinesiologists, accountants, and others—it is reassuring that the core disciplines employing the application of the basic sciences (chemistry, physics, and biology) to the analysis of physical evidence is still alive and covered extremely well by Bell in the *Encyclopedia of Forensic Science, Revised Edition*.

—Robert C. Shaler, Ph.D.
Pennsylvania State University
Professor, Biochemistry and Molecular Biology
Director, Forensic Science Program
Retired Director of the Forensic Biology Department
Office of Chief Medical Examiner, City of New York

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Forensic science is a field growing larger every day and no one person could ever hope to grasp it all. This book would have been impossible without the assistance of dedicated and generous forensic scientists who volunteered their time, advice, expertise, and library of photos to this effort. Aaron Brunedelle (Idaho State Patrol and later Washington State Patrol and Arizona agencies) supplied many fine images, particularly of firearms evidence and microscopic images. Chet Park, also of the Idaho State Patrol, also provided images. Art Craig of the New Mexico Department of Public Safety (NMDPS) took photos of presumptive chemical tests and shared good times with me while we worked together in Santa Fe in the 1980s. I owe a debt to many New Mexicans in the State Patrol—past and present—for hiring me there and letting me earn my forensic wings. Other colleagues who graciously supplied images are Heather Schafstall (Oklahoma State Bureau of Investigation) and Bill Schneck of the Washington State Patrol and Microvision. My photo researcher, Ms. Suzanne Tibor, located a number of commercial images, and I greatly appreciate her efforts.

Many members of the American Academy of Forensic Sciences (AAFS) provided hours of time and assistance. First and foremost, I am indebted to Dr. R. E. Gaensslen of the University of Illinois (Chicago) not only for reviewing my DNA entries, but also for starting me in this direction when I was a graduate student. Teacher, scholar, and gentleman—no one could dare hope to find a better mentor. I also wish to thank Jim Hurley and the Executive Council of the AAFS for assisting in finding reviewers and ensuring that this book was the best it could be. Barry Fisher, Max Houck, and Dr. Bruce McCord were gracious enough to review the text in the first edition on behalf of the Academy and to provide feedback and suggestions. Reviewers are often unsung heroes, and I extend a hearty thanks to all for their time and effort. A special thanks to Dr. Robert Shaler of Pennsylvania State University for career support and the preface.

Finally, I wish to thank the wonderful folks at Facts On File, particularly Frank K. Darmstadt, executive editor, who is a joy to work with and the walking definition of “professional.” I am proud to be associated with a company that is dedicated to education, particularly of young people. I am grateful to have been given the opportunity to produce this book under their expert guidance.

INTRODUCTION

The two words *forensic* and *science* each relate to the common theme of truth, either spoken or seen. The word *forensic* can be traced to the Latin *forum*, or “in the public.” The definition is roughly translated as “to speak the truth in public.” In the modern world, this extends to speaking the truth in court, today’s equivalent of the forum. Thus, the role of science is to help society define what is fact; the role of forensic science is to help the legal system define it.

As a recognized scientific field, forensic science is a relative newcomer, yet it represents a natural expansion of existing disciplines such as chemistry, biology, geology, medicine, anthropology, engineering, and many others. The scope and depth of forensic science grows daily as new technologies are discovered and as our society becomes more dependent on the judicial system to solve disputes. At the same time, the public’s fascination with forensic science is surging as evidenced by the success of movies, novels, and television shows with forensic themes. Recently, the CBS television show *C.S.I.* has been among the highest rated dramas, resulting in a 2002 spin-off entitled *C.S.I.: Miami* and later, *C.S.I.: New York*. Novels such as those authored by Kathy Reichs and Patricia Cornwell top best-seller lists, and detective and police movies routinely integrate forensic science into their plot lines. Coupled to these fictional portrayals are real events such as the attacks of September 11, 2001, the anthrax mailings, the sniper attacks around Washington, D.C., in late 2002, terrorist attacks in Madrid and London, and the 2004 tsunami, in which forensic science was a highly publicized component.

With high levels of public exposure and awareness, particularly through entertainment, comes the need for public education. There is a danger that media coverage and fictional portrayals of forensic science can lead people to exaggerate and misunderstand the role, capabilities, and limitations of forensic science. This growing gap between forensic fiction and forensic science served as a primary motivation for this project, which grew from my experiences as a forensic laboratory scientist, researcher, and forensic science educator. *Encyclopedia of Forensic Science* represents my small contribution toward linking public perception of forensic science to its reality.

Encyclopedia of Forensic Science gathers the core topics of forensic science into one comprehensive volume and provides an overview of each. Interested readers will find resources in the references and appendixes for further investigation of topics of interest to them. These references range from textbooks to articles in professional journals, all of which are available at or through public or college libraries. The encyclopedia is richly illustrated with drawings and figures and supplemented with photographs—most

supplied by working forensic scientists in many different organizations. A color insert containing selected photographs provides additional detail in areas such as firearms, toolmarks, and DNA analysis. Fourteen essays interspersed throughout the encyclopedia describe how forensic science relates to areas such as drug testing in sports, privacy concerns, and the interface of forensic engineering and forensic science. One essay, "The Top Ten Myths of Forensic Science," deals directly with misconceptions about forensic science. In a larger sense, the intent of the encyclopedia is to provide students, teachers, and the public with a comprehensive and reliable reference that shows forensic science as it really is, devoid of romance, glamour, and hype.

TARGET AUDIENCE AND READERS

Encyclopedia of Forensic Science is geared to reach a wide audience ranging from students to working professionals. At the high school and college level, the encyclopedia can serve as the starting point for class projects or career research. General readers can use the encyclopedia to learn about timely topics and issues relevant to forensic science. Working professionals and forensic laboratories will find the encyclopedia a useful addition to their libraries, a quick and easy source of information on more than 600 forensic science topics.

ORGANIZATION AND CONVENTIONS

The International System of Units (SI) conventions have been followed in this book, the only exceptions being in entries or topics in which forensic scientists conventionally use other units. A Periodic Table of the Elements is provided in Appendix III, and references to these elements are provided as both names and symbols (for example, *arsenic* and As). Appendix II comprises an extensive list of the common abbreviations used in forensic science. For alphabetical ordering, the different areas of forensic science are listed in the order of their subject area. For example, forensic anthropology can be found under "ANTHROPOLOGY, FORENSIC." Similarly, biographical or other named entries are ordered based on last name. Thus, a discussion of the O. J. Simpson case is listed under SIMPSON, O. J.

TERMINOLOGY IN AN EVOLVING WORLD

As this volume went to press, issues were being debated within the forensic science community and the courts concerning the significance and uniqueness of pattern evidence such as TOOLMARKS and BITE MARKS, FINGERPRINTS, and DNA evidence. For example, successful DNA TYPING of 13 CODIS loci can result in a probability of duplication that, while not zero, is astoundingly small. However, whether it is correct to say that such a combination of DNA types can be considered unique (INDIVIDUALIZED) has not been fully resolved. Similar debates about the uniqueness of fingerprints and impression evidence continue. An understanding or qualifying statement such as "unique to reasonable degree of scientific certainty" is often appropriate and should be understood by the reader even if not stated explicitly.

Finally, the reader should know that every reasonable effort was expended to find reliable, peer-reviewed sources and to present a technically correct and balanced treatment of controversial subjects and cases. Two distinguished members of the American Academy of Forensic Science have reviewed the encyclopedia, while many more assisted with individual entries. However, these entries are not intended as a primary reference, but rather as an overview and gateway to the wealth of information available on the fascinating field that is forensic science.

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A

ABO blood group system The first human BLOOD GROUP SYSTEM discovered and the first used in forensic SEROLOGY. Although ABO typing was an indispensable tool in forensic serology for decades, DNA TYPING has largely replaced blood group typing.

The ABO system consists of antigens found on the surfaces of red blood cells (also called erythrocytes and commonly abbreviated RBCs) and corresponding ANTIBODIES in the serum. KARL LANDSTEINER discovered the ABO blood group system in 1900 and for a quarter of a century, it was the only one known. Confusion over naming conventions continued until 1941, when the U.S. military adopted the ABO standard. By the 1960s ABO typing of BLOODSTAIN and BODY FLUID evidence was commonplace in forensic laboratories.

The ABO system is a POLYMORPHIC blood group system, meaning that the antigens (and corresponding antibodies) have more than one observable variant (PHENOTYPES or "type"). These variants are summarized in the accompanying figure. In the serum portion of blood, a person will have the antibodies associated with the antigen *not* found on the RBC surface. For example, someone with Type B blood has B antigens on the surface of their RBCs and anti-A antigens in their serum. For blood transfusions, people with Type AB blood are considered to be universal recipients since their serum does not contain any anti-A or anti-B antibodies. Conversely, people who are Type O are universal donors since their RBCs have neither antigen. There is also an H antigen, and an anti-H antiserum that will cause O cells to agglutinate (see below), and so the notation ABH blood group system is sometimes

used. There are also subgroups within Types A, B, and AB, but these are not routinely used in forensic work. In the U.S. population, the approximate frequencies of the types are

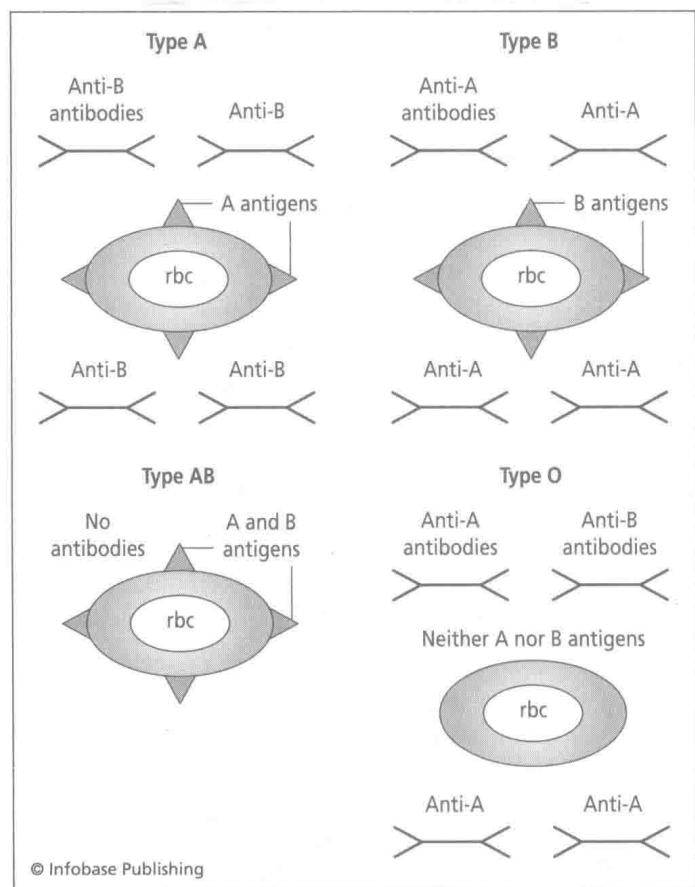
- Type A 42 percent
- Type O 43 percent
- Type B 12 percent
- Type AB 3 percent

In addition, a large percentage of people (~80 percent) are SECRETORS, meaning that the antigens present in their blood are also found in other body fluids such as saliva.

When antibodies react with corresponding antigens on the RBC surface, the cells clump together in a reaction called agglutination, which is illustrated in the figure. For example, if RBCs with A antigens on the surface (Type A blood) are mixed with serum containing anti-A antibodies (Type B blood), agglutination results. This was the process that, prior to Landsteiner's discovery, caused many people to die after receiving blood transfusions. In recognition of his life-saving discovery, he received the Nobel Prize in 1930.

Different tests were developed to type whole blood beginning in 1915 with the Lattes crust test. This test is applied to the serum and works by adding known blood cell types to the unknown serum and looking for agglutination. In 1923, Vittorio Siracusa developed the ABSORPTION-INHIBITION TEST, which detects the type of antigens on the RBC surface. ABSORPTION-ELUTION followed in 1930, and all of these tests,

2 absorption-elution and absorption-inhibition tests

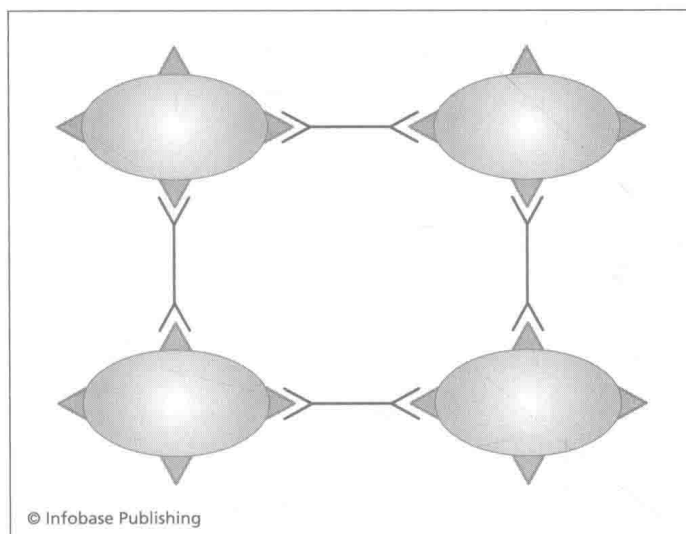


Components of ABO blood types. The antigens, shown as triangles, are found on the surface of the red blood cell (RBC), whereas antibodies are found in the serum. A person with Type A blood has A antigens and antibodies to B antigens (anti-B).

plus modifications and variants, have been applied in forensic serology.

Typing of blood and body fluids in forensic work usually involves stains rather than whole blood, and the stained material may be old and may have been subject to adverse conditions. There are no whole red blood cells left in dried stains since the cell membranes rupture when dried. However, the surface antigens survive and are more stable than the serum antibodies. Absorption-elution typing can be performed on very small samples (threads or fibers) and has been shown to work on stains that are 10 years old and older. It is also more sensitive than absorption-inhibition and is usually the method of choice.

A and B antigenic substances are common in nature, found in plants, animals, and insects. This introduces the danger of FALSE POSITIVE results if other biological material has contaminated a forensic sample. FALSE NEGATIVES are possible if the sample has



The process of agglutination, in which red blood cells clump in the presence of corresponding antibodies. For example, if Type A serum (containing anti-B antibodies) is mixed with Type B red blood cells, the B antigens will bind with the anti-B antibodies and form linked clumps of cells. The color insert contains a photograph showing agglutination.

been subject to harsh weathering or is very old. This illustrates a common problem in forensic science: often it is not the accuracy and precision of a testing method that determines its success; rather, it is the condition of the sample. Bloodstains are harder to type than whole blood; old, weathered, or damaged bloodstains are more difficult or impossible to type.

See also BLOOD.

Further Reading

- De Forest, P. R., R. E. Gaensslen, and H. C. Lee. Chapter 9: "Blood." In *Forensic Science: An Introduction to Criminalistics*. New York: McGraw-Hill, 1983.
- Saferstein, R. "Forensic Serology." In *Criminalistics: An Introduction to Forensic Science*. 7th ed. Upper Saddle River, N.J.: Prentice Hall, 2001.

absorption-elution and absorption-inhibition tests

Two tests that are used to type blood and BODY FLUIDS for ABO and other BLOOD GROUP SYSTEMS. Absorption-inhibition was developed in 1923 in Italy by Vittorio Siracusa, and absorption-elution followed in the 1930s. Many modifications and variants have appeared, and the general procedures have been applied to other blood group systems. Although red blood cells rupture when a bloodstain dries, the A and B antigens that are present on the cell surface persist.

As a result, these tests work on whole blood, body fluids (assuming the person is a SECRETOR), and in stains of any of those fluids.

Absorption-inhibition works by reducing the strength of an antiserum based on the type and amount of antigens present in the stain. For example, if the bloodstain comes from a person with Type B blood, the stain will contain B antigens. If an anti-A antiserum of a known strength is added to the stain, nothing will happen. If anti-B antiserum is added, some of the antibodies will bind to the B antigens, reducing the strength of the original antiserum. This reduction of strength is the inhibition for which the

test is named. Although effective, absorption-inhibition is less sensitive than absorption-elution and therefore requires larger samples. This presents a problem if the stain is very small or the amount of sample is limited, a situation often encountered in forensic analyses. Consequently, absorption-elution is more common in forensic applications.

The absorption-elution test is illustrated in the accompanying figure, using a stain of Type B blood as the example. Antiserum containing both anti-A and anti-B is added to the stain. Anti-B will bind to the B antigens and will remain behind when the stain is rinsed with cold saline. The stain is then heated, breaking the bond between the B antigens and anti-B antibodies. The solution into which the anti-B antibodies have eluted is then split in half. To one portion, A cells are added and to another, B cells. Agglutination (clumping) will be observed with the B cells, confirming the type of the original stain. Absorption-elution techniques work on samples as small as a single fiber and have been shown to work on stains that are a decade old or older. Absorption-elution is rarely used now given that DNA TYPING has essentially replaced traditional typing techniques.

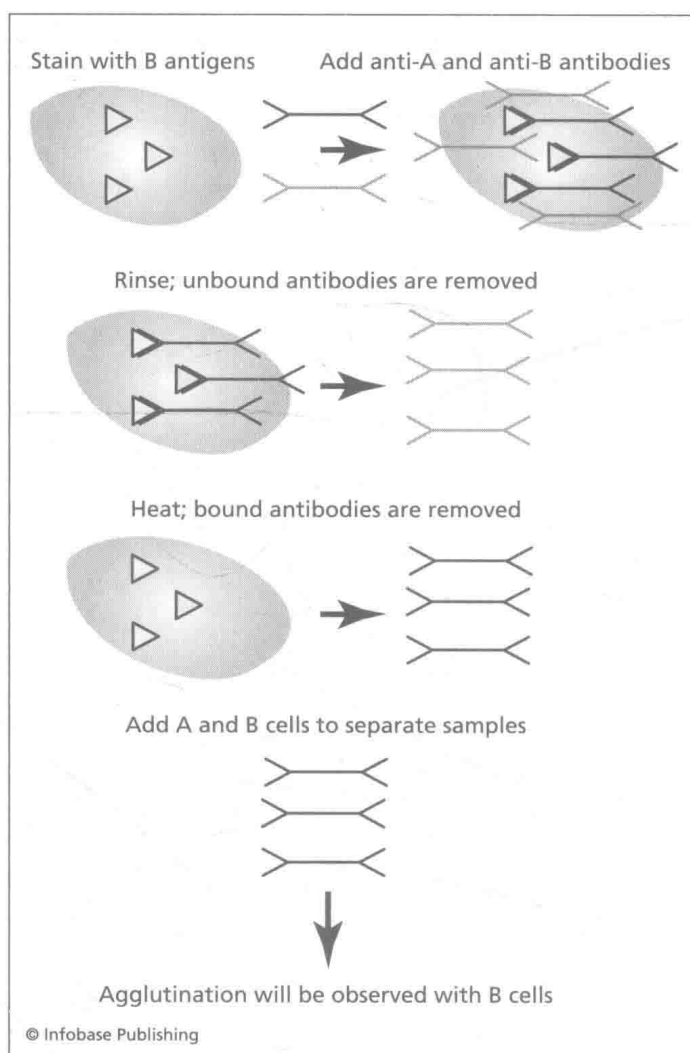
See also ABO BLOOD GROUP SYSTEM; BLOOD; BODY FLUIDS.

Further Reading

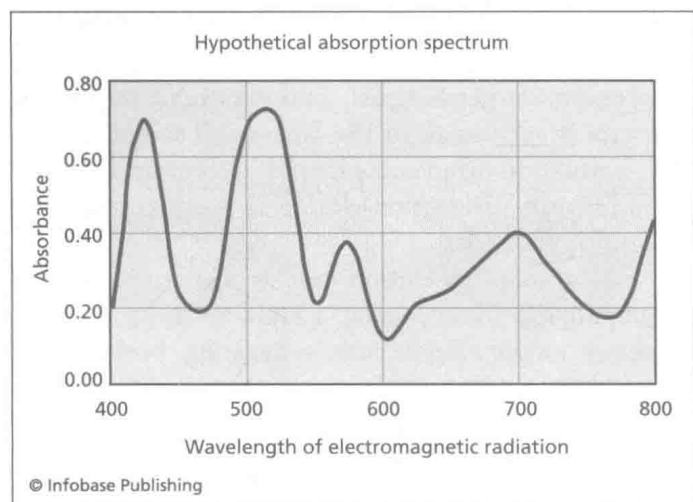
Saferstein, R. "Forensic Serology." In *Criminalistics: An Introduction to Forensic Science*. 7th ed. Upper Saddle River, N.J.: Prentice Hall, 2001.

absorption spectrum A graph that plots the absorbance of ELECTROMAGNETIC RADIATION (EMR) by a selected material as a function of the wavelength of radiation. Although commonly associated with the visible portion of the electromagnetic spectrum where colors correlate with wavelengths, an absorption spectrum can be generated in any spectral range. In forensic analysis, the most common types of absorption spectra used are those in the visible range (VIS), ultraviolet (UV), and infrared (IR). For example, an absorption spectrum of a DYE can help characterize FIBERS and INKS while an infrared absorption spectrum is a standard component of DRUG ANALYSIS.

Instrumentation (generically called SPECTROPHOTOMETER or SPECTROMETER) is required to generate an absorption spectrum. For creating a spectrum of a material in the UV/VIS range, the instrument is called a UV/VIS spectrophotometer, whereas an instrument that



Depiction of the steps in an absorption-elution test for ABO blood type. In this example, the bloodstain is Type B, which would contain B antigens. As a result, the stain will react with anti-B serum. After rinsing and elution, the eluted solution will contain the liberated anti-B antibodies that will agglutinate with B cells.



Absorption spectrum is a plot of wavelength of radiation versus the amount of that radiation absorbed by the sample being analyzed. The higher the point (here, the greater the absorbance), the greater the amount of radiation absorbed.

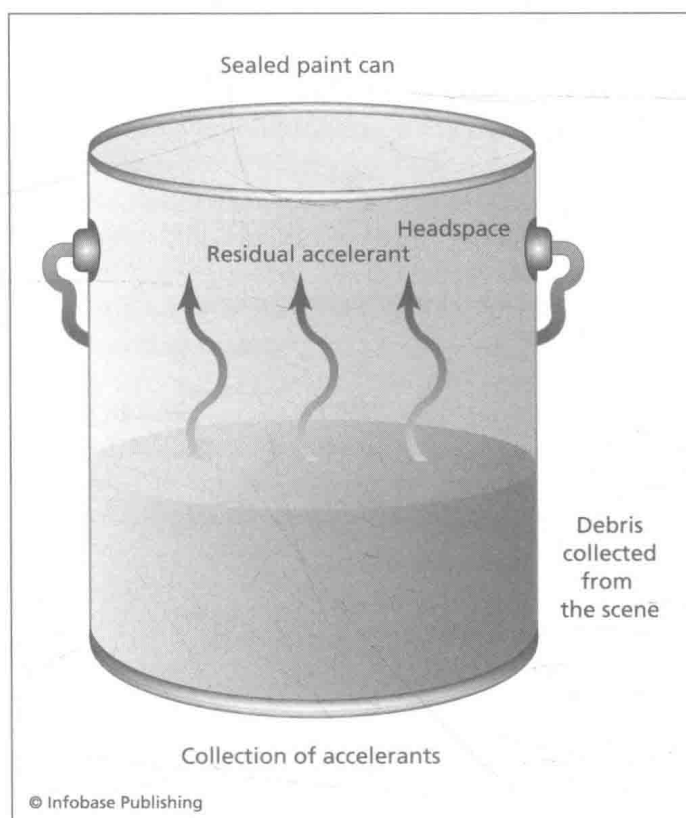
works in the infrared range is called an IR spectrophotometer. In general, the function of the instrument is to break up radiation into individual wavelengths that are then directed at the sample. The amount of energy absorbed by the sample at each wavelength is plotted to produce the spectrum. Different instrument designs exist and many techniques can be used to generate the spectrum, but the result typically is a plot of the absorption versus wavelength, as illustrated in the figure above. The pattern of the spectrum provides valuable chemical information about the sample from which it was generated, and in some cases is sufficient by itself to identify the substance specifically and unequivocally.

accelerant In ARSON cases, an accelerant is the flammable material that is used to start the fire. Accelerants can be solids, liquids, or gases, with gasoline being the most commonly used. Solid accelerants include PAPER, fireworks, highway flares, and black powder. Butane (cigarette lighter fuel), propane, and natural gas are examples of gaseous accelerants, which do not leave any residue at a fire scene. However, gases must be contained and transported, so severed gas lines or spent containers serve as critical PHYSICAL EVIDENCE in such cases.

Liquid accelerants fall into two broad categories: petroleum distillates, which include gasoline and other petroleum products; and nonpetroleum products such as methanol, acetone (used in nail polish remover), and turpentine.

Petroleum distillates are derived from crude oil and are also called hydrocarbons or petroleum hydrocarbons. In crude oil, volatility of the individual components range from extremely volatile substances such as propane (a gas at room temperature) to asphalt, which remains solid even at high temperatures.

Petroleum distillates such as gasoline and kerosene are not single hydrocarbons but mixtures of different components with similar volatilities. The volatility of an accelerant is an important consideration in the COMBUSTION process, determining how much residue will be left and how quickly it will evaporate after the fire is out. Related to volatility is the flash point, defined as the temperature at which a liquid will give off enough vapor to form an ignitable mixture. For gasoline, the flash point is -50°F (-45.56°C). The National Fire Protection Association (NFPA) defines a flammable liquid as one with a flash point of less than 140°F (60°C).



Collection of residual accelerants from evidence collected at an arson scene. The debris is placed in a sealed paint can such that empty headspace remains above it. When the can is sealed, the volatile accelerants continue to evaporate, and the vapors will collect in the headspace, which can then be sampled for further analysis.