INTERNATIONAL FORENSIC SCIENCE AND INVESTIGATION SERIES

Scientific Examination of Documents

Methods and Techniques

Fourth Edition

David Ellen Stephen Day
Christopher Davies

CRC Press
Taylor & Francis Group

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Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed on acid-free paper

International Standard Book Number-13: 978-1-4987-6803-0 (Hardback)

Library of Congress Cataloging-in-Publication Data

Names: Ellen, David, author. | Day, Stephen P. (Forensic scientist), author. | Davies, Christopher (Document examiner), author.
Title: Scientific examination of documents : methods and techniques / Stephen P. Day, David Ellen, and Christopher Davies.
Description: Fourth edition. | Boca Raton, FL : CRC Press, [2019] | David Ellen is the main author on all earlier editions of this work. | Includes bibliographical references and index.
Identifiers: LCCN 2018002263| ISBN 9781498768030 (hardback : alk. paper) | ISBN 9780429491917 (ebook)
Subjects: LCSH: Writing--Identification. | Legal documents--Identification.
Classification: LCC HV8074 .E45 2019 | DDC 363.25/65--dc23
LC record available at https://lccn.loc.gov/2018002263

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http://www.crcpress.com

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Preface

When the first edition of *The Scientific Examination of Documents* was published in 1989, the comparison between document examination and forensic handwriting was at a highpoint; physical documents were an important part of most transactions and the signature was a primary means of identification. Since then most financial business has moved on-line and the documents involved tend to be there for re-assurance, rather than having lasting validity. Handwriting itself has become a less practiced skill but is often found in many non-financial crimes. Notwithstanding these changes, it is still important for the investigator, lawyer, or forensic scientist to have a good understanding of how the forensic examination of a document might yield useful information to assist an enquiry. Arguably, the role of this book is now more important as what was common knowledge in 1989 is now becoming obsolete and consequently clues that could help an investigation are being overlooked.

In updating this book, David Ellen, the original author, has enlisted the help of Dr. Stephen Day and Dr. Chris Davies to review and where necessary amend the text for the modern world. While much of the detail on handwriting comparison has been left largely as in the original, the chapters on office technology and analysis of materials, and sections on interpretation and validation have been re-written by these authors. The result, we hope, adheres closely to the original intention of providing an outline of the subject to those outside the discipline who have a professional interest in the subject, but can also be of value to trainees in document examination. The approach is always to consider the whole document in an investigation and not concentrate on one aspect.

In developing the reference and further reading lists at the end of each chapter, we have left in the original citations where they are still relevant, but have also reviewed and added more recent references as needed. We also debated whether to include a chapter on typewriting comparison as instances of this method of production are now rare; however, we decided that it contains many of the fundamental principles used in examining more modern output, and decided to include it as otherwise the knowledge would be lost. In accordance with the publisher's style, American spellings have been used in this edition.

Acknowledgments

We acknowledge the assistance of the publishers who have patiently waited for us to make this revision and assisted at every step of the way, and thank Foster and Freeman Ltd for supplying the updated images.

Authors

David Ellen was in the field of forensic science for 43 years. For 29 of these years, he specialized in the forensic examination of questioned documents, mostly in the Metropolitan Police Forensic Science Laboratory, London, England, and also in the Forensic Science Centre in Adelaide, South Australia, then in private practice in London. He was secretary of the Questioned Document Section of the meeting of the International Association of Forensic Sciences in Adelaide in 1990 and has trained and inspired a generation of new document examiners. He is now retired.

Stephen Day has a BSc and PhD from the University of Bristol. He began his career as a document examiner at the Metropolitan Police Forensic Science Laboratory in 1981, transferring to the UK Home Office Forensic Science Service in 1993 to become head of their Questioned Documents team. He has examined thousands of documents and appeared in court on numerous occasions as an expert witness. He acted as the lead scientist for the discipline within the Forensic Science Service between the years of 1999 and 2006, during which time he chaired the European Questioned Documents Working Group for the European Network of Forensic Science Institutes from 2002 to 2004. In 2011, Steve joined the University of East Anglia to become course director for the Forensic and Investigative Chemistry MChem degree program. This has meant broadening his knowledge in all aspects of forensic science. He still lectures at UEA as a senior lecturer in forensic chemistry.

Christopher Davies started work in the Metropolitan Police Forensic Science Laboratory in 1981, where he was trained in questioned document examination. He continued to work in London when the Metropolitan Police Laboratory became part of the Forensic Science Service in 1996. He became one of the senior document examiners responsible for dealing with serious crime, including counter-terrorism cases. In 2010, he left the London laboratory when the Questioned Documents Section there was closed and continues to work as an independent consultant. He is also the ISO/IEC 17025 technical assessor for questioned documents for the United Kingdom Accreditation Service.

Introduction 1

Within the wide field of forensic science, the scientific examination of documents has one purpose: to provide information about the history of a document for the benefit of a court of law or, before that, to an investigating police officer or other investigating agent seeking evidence that might be present in the document. The same philosophy that pervades forensic science applies to document examination—the application of scientific methods and techniques to the problems relevant to the situation.

Scientific Method

The scientific method is a way of thinking. It is about the study of observed phenomena and the seeking of a correlation between them based on the philosophy that there is order and consistency in the universe. Observations about the heavens, animals, or chemical changes can be and have been made for many centuries, but it is the essentially scientific process of discovering a pattern behind these observations that has led to the technological progress of the last century or so.

The scientific method of correlating observations is to construct a hypothesis and test it by other observations, measurements, and specially devised experiments. If these confirm the hypothesis, it stands, but if not, a new hypothesis must be sought and tested. Thus a corpus of knowledge is built up that can be relied upon to provide a basis for extending the process further.[1]

Science, however, is more than philosophy; it has a purpose. The exploitation of scientifically based discoveries, mostly for the good of mankind, has been the hallmark of the nineteenth and twentieth centuries (and continues into the twenty-first century), but another benefit has been in the development of methods of analysis to determine, for instance, the presence or proportion of components or impurities in many substances.

Analytical Methods

Analytical methods are based on the testing of the material in question against the background of knowledge of the subject. To show, for instance, that the sulfate ion is present in a solution, barium chloride can be added. The resulting precipitate indicates that it is there, because barium sulfate, which is insoluble, is always produced in these circumstances. The corpus of knowledge of the chemistry of barium and its compounds is the basis of confidence in the results. A similar dependence on totally consistent and reproducible results is the basis of other analytical techniques of far greater complexity. By these methods, qualitative and quantitative analyses of many materials are carried out.

Such scientific analyses are of value in many fields, one of which is the investigation of crime and other matters of concern in courts of law. Forensic science employs many analytical techniques to identify, measure, and compare. The identification and measurement of drugs and alcohol employ relatively conventional methods similar to those used in other fields of qualitative and quantitative chemical analysis. Comparison is important in many fields of crime investigation. Traces of blood, glass, paint, and fibers are left at scenes of crime or are transferred from the scene to the culprit. Similarly, marks made by tools, fingers, or shoes of the attacker can be found at a scene. It is of importance to show whether the traces or marks match their possible origin and, if they do, how likely it is that they could have come from a different source. Similarly, identification and comparison are essential in the forensic examination of documents.

Since the publication of the first edition of this book, there has been increasing pressure on all forensic scientists to be able to demonstrate the reliability of their analyses and justify their opinion, and questioned document examiners are no exception. Risinger, Saks, and Denbeaux wrote several papers publicly criticizing the discipline for a lack of standards, lack of consistency, and absence of external quality control procedures, equating handwriting comparison to witchcraft.[2,3] Since that time, efforts have been made to improve the situation. Regulators both here in the UK and in the United States have required detailed standard operating procedures and standards to be written. In the United States, the American Society for Testing and Materials (ASTM) has published a series of standards covering a range of forensic sciences,[4] including some aspects of document examination, and in Europe, the European Network of Forensic Sciences (ENFSI) established working groups in various disciplines that are responsible for developing and maintaining standards. Two of relevance to questioned document examiners are European Network of Forensic Handwriting Experts (ENFHEX) (handwriting) and European Document Examiners Working Group (EDEWG) (other aspects of document examination), and both have written standards on a number of processes. Independent Australian researchers led by Found and Rogers have instigated quality assurance tests to establish the expertise of handwriting and signature comparison,[5] and most major laboratories in the United Kingdom have to acquire ISO 17025, independently assessed by the UK Accreditation Service (UKAS) before they can practice in the criminal justice sector. As a consequence, there has been a continuous improvement in the standards associated with document examination over recent years. While none of this can accredit a specific opinion—people can still make mistakes—it gives individuals and organizations a track record that can be inspected; one no longer has to rely solely on the reputation of an individual, and longevity is no longer a measure of expertise.

Documents

A convenient definition of a "document" is a physical item that contains written or printed information. Much information can now be stored electronically, and this is outside the scope of this book. At first it might be considered that there is little requirement for a forensic document examiner in the modern electronic age—the day of the paperless office, the cloud, virtual accounts, and encrypted information shared on multiple electronic devices is here, and there much less reliance on the printed contract, handwritten check, or authenticated signature than there used to be. However, walk into any modern office and the myth is soon dispelled; sticky notes on computers, lists, reference numbers, printed emails, and photocopies are all documents that could be relevant to an investigation. The scope and variety may be broader, but the general principles remain. Documents considered in this book are those normally made of paper, but other materials, including boards, walls, or even bodies, can bear written messages.

The information contained in a document can be considered as occurring at two levels: the superficial, where what is conveyed by the document is expressed in writing, typewriting, or printing, or a combination of any of these, and at a deeper level, where other, less obvious, evidence can be found. It is in the latter field, which is the province of the document examiner, where information about the identity of the writer, the source of the typewriting or printing, the presence of traces of erased entries, and many other factors can be discovered. The significance of such discoveries can be of interest to many people in different occupations, but it is when documents contain incriminating information that their origins are the concern of investigating police officers and, later, the courts. If a document is not what it seems but once bore different information now removed or altered, the deceit it carries in itself will be of vital interest to a civil or criminal court. It is for these reasons that most scientific examinations of documents are carried out by forensic document examiners, whose conclusions are put before the court as written statements or given orally as expert evidence.

Material properly deduced from a document by comparing it with one or more other documents can provide invaluable evidence on which a judge or jury may reach a decision. A connection between a crime and an individual, or the exclusion of that individual from the investigation, can be established. The principle involved in all of these comparisons is the same as that already referred to in other branches of forensic science: the testing of various parameters and reference to the background knowledge of the subject in order to reach a conclusion. Similarly, information can be adduced from a document by methods other than comparison. By the exploitation of methods that detect more than the eye can see, facts that are of value to an investigator or to a court of law can be obtained.

Thus, the scientific method is now established as the correct and proper way of evaluating such evidence provided by documents. It is not the only way; there are still practitioners all over the world who use methods that cannot be so described, and many express erroneous opinions through not following basic principles.[6] Conclusions are reached and stated with great certainty on insufficient evidence, and the value of proper deduction is underestimated. This is particularly true in the case of handwriting comparison, where "experts" practice without the benefit of proper training or methods, working on instinct and in their own unconventional ways. Most document examiners, however, follow the standard methods outlined here and provide an invaluable service to investigators and courts. The reader should note that there are two types of handwriting examiner—forensic document examiners (FDEs) and graphologists. This book concerns itself with the skills of the former in identifying authorship; graphology is an expertise in its own right, used, for example, to infer a person's character, but it rarely has a place in criminal investigation. (see "Document Examiners" below for further comment).

In any science, there are areas of uncertainty; the complete knowledge of a subject is never obtainable. In some, especially those allowing accurate measurements to be made, an analysis based on these provides precise results. Much of the work of the document examiner falls into the former category. Handwriting comparison does not, at present, permit exactly reproducible calculations of likelihood, although attempts have been made to do this.[7] While precise measurements are possible, there must still be an element of interpretation based on experience, and consequently, the probability that two writings came from one source cannot be calculated. This is true of most forensic science disciplines (except for DNA databases), and precision should not be confused with accuracy. This means that some degree of subjectivity must be present; without a technique that automatically produces the exact result, any analytical method must depend on the experience and ability of the analyst.

In every analytical method, the limitations must be appreciated. It is erroneous to express any conclusion with a certainty that does not recognize the limitations of the method and the accuracy of the observations on which it is based. However, although these limitations exist, conclusions can be properly drawn if these limitations are recognized; the danger of wrong results occurs when they are not.[7]

In handwriting comparisons, proper account must be taken of complexities such as the variations found in the writing of one person that at first seem to indicate another writer or, conversely, the possibility of accidental coincidence of a number of similarities in the writings of two people. In addition, attempts at deliberate copying (simulation) of a person's writing or style and the wish to disguise one's writing to deceive or deflect suspicion are added factors in document examination that are not encountered in many forensic sciences and defy calculation. If these factors are not taken into account, false attributions can be made.

Document Examiners

The work of the forensic examiner of questioned documents (the term "questioned" indicating that not everything about the document is accepted for what it appears to be) is described in this book. The man or woman practicing the profession may do so as a full or part-time occupation and may be referred to as a forensic scientist, forensic document examiner, document examiner, document expert, handwriting expert, or a combination of these and other descriptions. Document examiners may work in private practice or be part of a university, a national or local authority, or a police laboratory. They will normally be trained in a science or in another subject to the degree or doctorate level, the discipline required being decided by the tradition of the country. There is often a division in the types of examination carried out, handwriting being examined by different people from those who examine printed documents, alterations, and ink comparisons. The examination of identity documents and counterfeit money is another strand of document examination that can be separated into a different department due to the specific nature of the work.

Document examiners must take a holistic approach to the examination of the documents in front of them; they must consider the document in its entirety, not just the aspect or entry that has been drawn to their attention by the investigator. Although there are a number of techniques used in the examination of documents, it is not beyond the ability of a properly trained scientist to be able to tackle all of them to an adequate degree. However, as developments of sophisticated methods such as scanning electron microscopy and mass spectrometry play an increasing part in document examination, some assistance from specialists in these fields is required; a wide knowledge of all the available techniques is a great advantage in document examination. In any examination, there is likely to be considerable overlap of the techniques required. For instance, an entry written by another person in a different ink may not be considered separately from the bulk of writing on a page and therefore, if the inks are not compared, may cause confusion. If a signature written across a passport photograph needs to be authenticated, both its writing and its ink must be examined. Although handwriting comparisons and other examinations can be made separately, much is gained by a comprehensive study of the document.

Qualifications and Training

The wide range of disciplines involved in document examination does not lend itself to one single academic qualification. Chemists, physicists, and biologists can all claim that they have a function. In Germany, psychologists are widely employed for handwriting comparisons, not because they study the psychology of the writer, but because handwriting is regarded as an aspect of human behavior.

Whatever the discipline, scientific training is the most suitable basic qualification for those entering the profession of document examination. Where the techniques employed are taught in an academic environment, they are rarely taught to the level necessary to practice as a document examiner. Consequently, further on-the-job training is required before a person can be considered qualified. Document examination laboratories or sections of forensic science laboratories continually train new examiners, and, less frequently, those in private practice may take an apprentice assistant.

While the increased compliance with standards has already been discussed, it remains very difficult to accredit opinion. There are few diplomas that certify that forensic scientists are qualified to practice, but moves have been made to remedy this in the field of document examination. In the United States, the American Board of Forensic Document Examiners issues certificates of qualification. There is now no formal qualification solely for document examiners in the United Kingdom. The Chartered Society of Forensic Sciences has discontinued the range of diplomas, including that in questioned document examination, offered by its predecessor, the Forensic Science Society, and replaced it with a general formal status of competency that can be achieved in any discipline. In Australia, membership in the Australian Society of Forensic Document Examiners is regarded as a qualification because the society restricts its membership to those considered by their peers to be suitable.

Generally, however, the establishment at which a document examiner in the public service is employed will allow him or her to practice only when he or she has reached the required standard. This would be mandatory in any organization that desires ISO/IEC 17025 accreditation for questioned documents work. Those examiners not employed in the public service do not have to be tested in this way, but have to build up their own reputations. Many examiners in private practice have been previously employed in the public service and have received their training in established laboratories.

Not every practitioner in document examination has been properly trained or has acquired adequate knowledge or ability to perform the work to the required standard. Without available qualifications that ensure that proper training has been given and examinations have been passed, any person may set up in business and claim to be a document examiner. It is a regrettable fact that the client may not be able to distinguish the competent from the charlatan. Courts, when considering the quality of an expert before them, tend to put great store on experience. This is often a poor guide to ability; some of those who claim long experience show little competence to do the work properly.

There is, therefore, a problem for those who require a comparison of handwriting and need to choose an expert to assist them. There is also some confusion between those practicing graphology, which aims to assess the personality of the writer, and those who work in forensic handwriting examination. The confusion is not helped by some graphologists who erroneously appear to see no difference between the two disciplines. Perhaps the term "handwriting expert" is one cause of the confusion in that it can be applied to both areas. The term in its legal sense is a definition of those who give expert evidence in court. The expertise is that which the court requires and does not include a variety of other studies that might be deduced from the examination of handwriting. Because the description can be applied to other aspects of the subject, care must be taken to distinguish between the different expertises when looking for the right person for the job.

Objects of This Book

This book describes in outline the principles, methods, and techniques employed in forensic document examination. It is aimed at lawyers, police officers, and other investigators to enable them to understand the basis of the science. It is not intended as a textbook for document examiners—the detail is sufficient only to introduce the subject; but, as it deals with the essential requirements of the discipline, it should serve as a guide to those entering the profession. It may also be of some assistance to those already in practice.

The description of document examination is divided into chapters according to the subject of examination. Handwriting comparison is given coverage greater than any other subject because of its complexity and importance. The features found in handwriting and their variations occupy two chapters. The third chapter on handwriting discusses how expert conclusions on handwriting are reached, and a fourth describes what is required from the investigator for a handwriting comparison to be carried out. These are followed by chapters on typewriting, analysis of document materials, and the use of printed documents. Other aspects of document examination are considered in Chapters 9 and 10 before the final chapter which discusses some aspects of the presentation of findings to a court.

Literature on Document Examination

Books

A number of books on document examination have been produced, some more detailed than this; they have been of variable quality and therefore of variable importance. Document examination has also been referred to in more general books covering forensic science. Many of these are now out of print, but some have been reprinted by other publishers.

The first book of note in document examination to be written in English was A. S. Osborn's *Questioned Documents,* published in the United States by Boyd in 1910 and 1929. The most significant publication in the United Kingdom was W. R. Harrison's *Suspect Documents* (Sweet & Maxwell, London, 1958 and 1966). The works of both Osborn and Harrison have been reprinted by Nelson Hall of Chicago. Other books, *Scientific Examination of Questioned Documents* by Ordway Hilton (CRC Press, Boca Raton, FL, 1993), *Evidential Documents* by James V. P. Conway (Charles C. Thomas, Springfield, IL, 1972), and *Handwriting Identification: Facts and Fundamentals* by R. A. Huber and A. M. Hendrick (CRC Press, Boca Raton, FL, 1999) are also highly regarded. Standard textbooks in German are *Gerichtliche Schriftvergleichung* by Lothar Michel (de Gruyter, Berlin, 1982) and *Forensische Handschriftenuntersuchung* by Manfred R. Hecker (Kriminalistik Verlag, Heidelberg, 1993). *Document Examination on the Computer: A Guide for Forensic Document Examiners* by Gary Herbertson (WideLine Publishing, Berkeley, CA, 2003) deals with aspects close to the work of forensic document examiners not covered in this book.

Journals

Like any other profession, forensic science has organizations dedicated to its advancement that publish journals and organize meetings. Many papers are written for these publications or are read at meetings and, through these, advances in the subject are made known. Document examination, as a branch of forensic science, is well represented in these areas.

Journals that publish papers on document examination include, in the United Kingdom, *Science and Justice*, formerly the *Journal of the Forensic Science Society*, and *Medicine, Science and the Law*; in the United States, the *Journal of Forensic Sciences*, *Forensic Science Review*, and *Forensic Science*

International; in Canada, the *Journal of the Canadian Forensic Society*; and in Germany, *Kriminalistik* and *Archiv für Kriminologie*. Also, the *Mannheimer Hefte für Schriftvergleichung* specializes in the subject. The *International Criminal Police Review,* published by the International Criminal Police Organisation, also prints articles on document examination, but these are for limited circulation. Periodicals devoted entirely to document examination are the *International Journal of Forensic Document Examination*, introduced in Canada in 1995, and the *Journal of the American Society of Questioned Document Examiners*, produced in the United States since 1998.

Meetings in forensic science are arranged every three years by the International Association of Forensic Sciences, the European Network of Forensic Science Institutes (ENFSI), and annually by the American Academy of Forensic Sciences. These include sections on document examination, as do meetings of the Chartered Society of Forensic Sciences in the United Kingdom. This latter body has also arranged meetings on document examination, and symposia are regularly held on the subject in Germany. The American Society of Questioned Document Examiners holds a meeting every year for its members and invited guests. Other national organizations in Canada, Australia, India, and other parts of the world hold regular gatherings.

In this book, references to papers published in the abovementioned or other journals and publications are listed at the end of each chapter, and some are also cross-referenced in the text and are listed separately. These are relevant to what has been discussed in the chapter and cover parts of the subject in greater detail. It is impossible to refer to every paper, but emphasis has been given to the more recent publications.

Research and Development

Document examination makes progress by the development of new techniques, some of which are invented by document examiners, while others are adaptations of advances made elsewhere in science. For instance, the electrostatic detection of indented impressions, the use of the laser, visible light spectroscopy of inks, liquid chromatography of ink, and pattern recognition techniques for the examination of handwriting have been introduced, and these are not the only examples of progress in the field.

It follows, therefore, that this book will be in some ways out of date before it appears and will become increasingly so. This is inevitable in any book covering a scientific subject. In this edition, we have sought to update the techniques where significant changes have occurred and to reference key papers so that the interested reader can explore the technique further. Further changes have been, and will be, brought about by changes in office technology. Different problems are caused by new methods of producing type on paper and by modern methods of printing and photocopying. However, most of the general principles and methods described here are likely to remain unchanged or modified only to a small extent. The employment of the scientific method through whatever technique is used will remain the most important factor.

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Handwriting
The Variations between Normal Writings

2

Introduction

In courts of law, expert evidence is frequently given on handwriting, and the giver of that evidence is not unnaturally described as a handwriting expert. This epithet can be misleading. It seems to imply that this is a person who knows all about handwriting. They know how many different scripts there are now and in the past, how they have developed, how they are taught, how they are affected by difficult circumstances, why people write the way they do, and so on. In fact, this is not the case. It is true that there are people who study the development of scripts used by different peoples, others who study handwriting to discover the personality of the writer, and others who specialize in the teaching of handwriting. All of these can be described as experts in handwriting, but that description when used in courts of law applies to those who perform a task within clear limitations. They are concerned with identification of the writer of a piece of questioned writing, the recognition of simulated signatures, and other related matters.

To do this on a scientific basis, it is necessary to build up background knowledge by studying handwriting in many different circumstances. Thus, to identify the handwriting of an individual, it is necessary to know how the writing of one person differs from that of another and how the writing of one individual varies. It is not necessary to know why one person writes the way he or she does, or to know how someone was taught to write or what teaching methods are available, but some knowledge of these basic facts can be of assistance. More important is the study of what is found in writings on documents—how they can be examined to determine whether they have a common writer. This and the following two chapters describe the way this is achieved.

In this chapter, natural handwriting is considered and how it varies within the output of one person and between different people. In Chapter 3, differences caused by accidental events or deliberate actions are described. Chapter 4 discusses how the background knowledge referred to in Chapters 2 and 3 is used to reach conclusions on the examination of handwriting. Chapter 5 considers collection of samples, a peripheral but important aspect of forensic handwriting comparison. Because of the relationship among the contents of the four chapters on handwriting, some repetition of certain points occurs in the chapters; this is necessary to avoid too much cross-referencing.

Variations in Writing

Writings made in England in the twenty-first century have much in common with each other and differ, to varying degrees, from writings from earlier centuries. Similarly, they are different from contemporaneous French writings. The beautiful copperplate style of the Victorian period is rarely found today. A figure *1* with a long stroke at the left is common in France; a letter *s* ending with a tail is common in the United States, while both are rare in England.

These "class" characteristics derived from the taught style or from regional influence may give an overall similarity in appearance to the writing of different people from the same background. In this book, these features will be referred to as style characteristics when discussing handwriting. But even within a single country at a particular time, there are other variations in style caused by different teaching methods. The teaching of these styles will obviously influence the writing of those who learn from them, but no teacher has ever succeeded in making all his or her pupils write in precisely the same way.[1] In fact, most schoolteachers find that they can recognize each child's writing at an early stage of the acquisition of the ability to write. Thus, "personal" characteristics, specific to the individual, quickly develop, and it is these that are most useful to the forensic handwriting examiner.

Although it is true to say that having learned to write in a particular style, and having diverged from it in an individual way, one therefore has a unique method of writing, clearly distinguishable from that of any other person, more is required. It is necessary to find out more about this individual method, how it varies within itself, and how it differs from those of others.

A complicated action such as the manipulation of a pen into producing universally recognizable shapes using a combination of the muscles of the arm, hand, and fingers controlled by the brain both consciously and unconsciously is clearly likely to give rise to wide variations in method and effect.

Whatever their cause, the examiner of questioned documents must build up a background knowledge of these variations, systematize them if possible, and discover whether any order prevails.

Block Capital Writing

The roman script used in Western European languages can be written in three forms: capital writing, cursive writing, and disconnected script, which is usually written like cursive writing but not connected. Block capital writing will be considered first.

Methods of Construction

It is sometimes thought that block capital writings do not differ much from person to person, but this is not correct. Consider first the capital letter *E*. This can be shaped in two ways: one as a vertical semicircle with a horizontal line in the middle and the second as the more common rectilinear shape. This consists of four specially arranged lines that together are recognizable as a letter *E*. To construct this letter with a pen, each stroke must be made separately, but, if they are all present, the order in which they are made is immaterial. Any one of the strokes can be executed first, and any of them can be made in either direction. There are therefore many ways in which this letter can be constructed simply by varying the order and direction of the production of the strokes. The number of ways could be increased if certain of the strokes are joined to others without lifting the pen. In theory, then, a representative sample of many writers could be found wherein each writes the letter in a way that differs from that of each of the others.

In practice, this is not found. Only a few of the theoretically possible methods are used, presumably because some are easier to execute than others. Writers choose subconsciously to employ the way that is easiest for them. Some methods are frequently found, and others less so or rarely. The methods usually employed to write a block capital *E* are shown diagrammatically in Figure 2.1.

Similarly, all other block capital letters can be executed with different pen movements. Some, such as *C* and *S*, are written with a single stroke, rarely made other than from top to bottom, so little variation can be found in this aspect. Other letters, being more complicated, afford greater possible variation. In some letters, a different pen movement will result in a slightly different shape. Thus, a *G* can be made with the bottom right-hand straight stroke either horizontal, vertical, or vertical with an additional horizontal added above it. In the last alternative, the complicated shape at the bottom right of the letter can be made in at least three different ways.

Other letters that provide alternative shapes are *I* and *U*. The letter *I* is sometimes written with a dot, and the letter *U* with an extra down-stroke on the right, both forms not strictly correct in the block capital forms of the letters, but not infrequently found. The letter *I* can also be written with horizontal strokes at the top and bottom. The letters *H* and *K* are sufficiently complicated to afford different methods of construction. In the making of a block capital letter *H*, the first stroke to be made is usually the left-hand upright, but after that, either the right-hand upright or the horizontal stroke can be made next. The down-stroke of the letter *K* is also usually the first made, but the two diagonals can be made in several different ways (see Figure 2.1). In making the letter *T*, either stroke can be made first.

Figure 2.1 Different methods of construction of block capital letters.

A number of letters, such as *B* and *D*, consist of a down-stroke and a curved remainder. As in most block letters, the first part to be written is the left-hand downstroke, but the rest can be made either by retracing this line and finishing the letter all in one stroke or by lifting the pen and making the rest as a separate entity. However, this difference is not always clear-cut. Sometimes the pen is only partly lifted, and the resulting thin line gives rise to doubt as to whether any distinction can be made between the two forms of the letters.

There are, then, various ways of making different block capital writings. Each individual writer will mostly adopt one method of construction for each letter without knowing why he or she chooses it, or even, without the fact being pointed out, being aware that these different methods of construction are available. Some forms are found mainly in writings made with the left hand because the natural movement away from the body tends to predominate. A letter *O* made in a clockwise direction is an example of this. It is unusual for one person to use more than one method of construction of any letter, although two distinct types of letter, such as a semicircular and a normal rectangular form of *E*, might be used in conjunction. This use of two forms and their relative frequency of occurrence is a characteristic of the writer in itself, and both forms are recorded for future comparison. There are exceptions to this. It is not uncommon for two forms of the block capital letter *N* to be found in the writing of one person. One form ends with the right-hand vertical stroke moving upwards and the other with the letter ending downwards. Also, letters made with a vertical stroke and a curved remainder, such as *B* or *D*, might be made in one or two strokes by the same writer, each being variations of the same method.

Determination of Pen Movement

The order in which strokes of a letter are made can be discovered in two ways. The first is to watch or record how the pen moves in the act of writing; and the second, the only one available to the document examiner, is to determine the method of construction from the written letter.

The movement of the pen in constructing the letters is determined by study of the continuous, unbroken lines of writing. Continuous lines can sometimes be confused with two lines that join but were not made in one movement. Similarly, what appears to be one stroke can be a retrace where the pen moves back along the same path on which it just traveled. The vertical line at the beginning of letters such as *A*, *R*, and *N* is likely to be a retrace if it continues to form the next part of the letter; it is rare for such strokes to begin at the bottom. Examination under a microscope giving approximately 20–40× magnification can usually establish whether a break occurs between two touching lines or whether the pen has changed its direction without being lifted from the page. Similarly, a retrace can be discovered by the finding of the beginning or ending of a line not exactly retraced.

The movement of the pen to form a letter can be determined even when it is lifted in the act of writing. The pen leaves the paper not like a helicopter rising vertically from the point at which it is resting, but gradually, like a fixed-wing aircraft taking off. In doing so, the line it makes becomes thinner, tailing off to nothing. However, unlike an airplane, the pen will often change direction to move toward its next landing place before it has finally left the paper. When the pen touches the paper again, it may be still traveling from its departure point and will alter its direction to form the letter after it has "landed." As the landing is also at an angle and not vertical, gradually thickening lines are produced. These beginnings and endings of strokes enable the pen movement to be determined. In some cases, the pen will not entirely leave the paper, and very thin connecting lines between the strokes will remain. Such evidence of pen movement can be found both within a letter and between letters.

Ink Lines

The line of writing itself can provide evidence of the direction in which it was made. The point of a ballpoint pen will be nearly devoid of wet ink when it begins to write a new line, so there may be a thinning of the deposited ink where the stroke begins. On some surfaces, the ink direction can be ascertained from the appearance of the crossing point between two lines. This is apparent when a pen using liquid ink writes on shiny paper. On close examination "tram lines" can be seen at the edges of the line. These are formed where the ink has concentrated before drying. A line crossing another will remove the tram lines of the first line and leave its own across the width of that line. Another method that, in the right conditions, can demonstrate the direction of the line depends on the build-up of ballpoint ink in the V between two crossing fibers of the paper. This can be seen if the ink is thinly applied. Magnification of around 100× is required.[2] When a ballpoint pen changes direction to form a curve, it may deposit excess ink immediately after making the curve. The positions of these "goops" in the writing line can indicate the direction of travel of the pen.

Striations

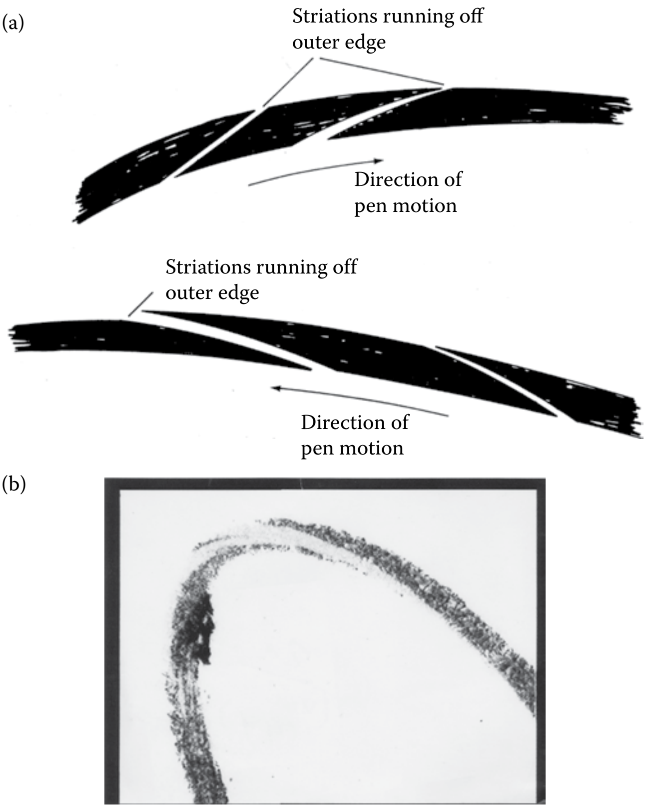
Another method depends on striations being present in the line made by a ballpoint pen. These are thin lines found within the line made by a pen and are caused by damage or dirt on the ball housing, which scrapes ink off the ball and prevents an even flow of ink. When such striations appear to run off the outside of the curve of a line, the line has been made in the direction in which the striation seems to be pointing. (Figure 2.2).[3] Experiments with an empty roll-on deodorant container will quickly demonstrate this phenomenon.

Not all of these methods will be certain to give a clear indication of line direction, but they will not give the wrong answer if properly applied. Normally, with several examples of each letter and employment of a combination of the methods described above, the pen movement can be established.

Proportion of Letters

In block capital writings, the method of construction of individual letters is not the only means of distinguishing between the writing of one person and that of another. Another way is in the proportions of each individual letter. When method of construction was considered, the forms referred to were for the most part discrete; they could be easily defined and did not gradually merge into each other. The exceptions mentioned were letters like *B* and *D*. With proportions within a letter, the parameters are not so easily distinguished. To say, for instance, that one writer's letter *O* is tall

(a)



(b)

Figure 2.2 (a) Determination of direction of stroke of ballpoint pen lines. (b) An enlarged photograph of a ballpoint ink line moving from the right to the bottom left of the picture. Note the striation crossing from the inside of the curve to the outside and the "goop" after the pen has completed the curve.

and thin and that of another is short and fat may be generally true but not easily demonstrated for every such letter. The human being is not a machine producing an identical product over and over again. As in every other activity, variations occur, and these variations are greater for some people than for others. Thus, when all the examples of a particular block capital letter in a sample of writing are considered, a range of variation of the letter proportions will be found that will be narrow or wide, depending on the consistency of the sample.

However, differences in proportion between the same letter written by different people are more subtle than mere descriptions of height or width. More complicated letters such as *B* or *S* may be wider at the top than at the bottom, or vice versa; the angle of curvature of part of one letter may be greater than it is in the same letter made by a different person. The height or width of one half of a letter *M* may consistently be greater in the writing of one person than in that of another. A more minute difference may occur in the letter *A* or others where an initial retrace is present. The letter will begin with a downstroke that is then retraced, but not usually exactly, so both lines can be seen. The point at which the first line begins may be above, level with, or below the top of the retracing upstroke. Although the relative positions of the beginning of the lines will not be exactly the same for each example of that letter in one example of writing, it will be within a range of variation that will be different from that found in the writings of many other persons.

There are, therefore, many possible variations in the proportions of each letter of the alphabet, and they are usually independent of the method of construction of the letter.

Proportions of Letters within Words

Proportions of letters within a word can be another discriminatory factor in block capital writings. Some writers make certain letters smaller than other letters. Sometimes, for instance, the letter *O* or *I* will be shorter than the other letters or the letter *P*, *R*, or *T* might be taller, the cross bar of the latter overhanging the adjacent letters. A letter *Y* might be written with its tail below the line or above it. Also, the position of the letter in a word or sentence may be significant—for instance, some writers habitually make the first letter in a sentence taller.

Another feature some people introduce into their writing is the use of lowercase script in what is intended to be block capitals. Sometimes all examples of one or more letters are written in detached lowercase script because the writer seems incapable of writing the appropriate block capital form.

This does not exhaust the ways in which block capital writings can vary from person to person. The actual pressure used to write indicated by the depth of the impression made into the paper, the quality of the line (that is, whether curves are smooth or shaky), whether some letters are joined to the next, the position of the writing on the page, whether margins are left, and the spacing between words can all produce variation between the writing of one person and that of another.

Numerals

The numerals 0–9 can be regarded in the same way as block capital writings. They, too, show the same sort of variation in method of construction and proportion. The figures *8* and *0* are variable in both the point at which the writing line starts and ends as well as in the direction of the pen movement, which can, as in the letter *O*, be related to the left- or righthandedness of the writer. Although they are sometimes the only questioned materials, numerals usually occur in conjunction with other writings. Other characters such as signs for the pound or dollar also give scope to a wide variation between writers.

Cursive Writing

Cursive writing is so called because it is running writing (Latin *currere*, "to run"). Unlike block capital writing, which is usually preferred if the main consideration is legibility, cursive writing has the advantage of rapid execution and speed of production. Other considerations apply as well. Some people are proud of the beauty of their handwriting and take great care over it; italic styles of writing are an example of this. More care is taken in teaching cursive than block capital writing, and there is a choice of styles available; the style taught is the choice of the teacher, school, or education authority. This choice is dictated by fashion, the invention of new methods, and other factors. Once the basic methods are learned, the pupil will modify them either to express individuality, because he or she cannot achieve the standard of the copybook, or for reasons too obscure to determine. Whatever the reason, it is clear from observation that, far from a teacher producing identical results like a printing press turning out copy, each person will produce something different both from that taught and from that produced by other pupils.

Development of Cursive Writing

The individuality of a person's own writing is often regarded by a child or adolescent as a form of self-expression, so experiments are made, methods are changed, and factors such as slope and size are altered according to the dictates of taste as well as to increasing skill. Eventually, usually around the late teens, a method is arrived at that is much more consistent and is likely to remain much the same throughout the life of the individual. Some people will develop more than one method, changing perhaps from italic to a more conventional style at will. Others can write in two very different ways, one when writing carefully and one when writing rapidly. Some people are ambidextrous and write somewhat differently with one hand than with the other. Very few people are truly ambidextrous when it comes to writing, as fluent with one hand as the other.

Although many people can write by more than one method of cursive writing, most cannot. This may sound surprising, as it is commonly believed that one's own writing can be considerably altered. In fact, what usually occurs is that the same basic method and underlying construction is used, but only the size of the writing, evenness, and control vary. The tendency to modify writing is not even. Some writers are very consistent, and they allow little to distract them from turning out their uniform products. Other writers are inconsistent for no apparent reason, and, even within a single piece of writing, size, slope, and neatness may vary.

Interpersonal Differences

Despite these personal variations, it is common knowledge that the writings of different people vary to a much greater extent. Most people, on receiving a handwritten letter, can recognize the writing of the sender. We all have a memory store of a number of familiar writings and can refer to these immediately. Normally, the comparison of the writing based on overall appearance (usually using "style" characteristics) with those stored in the memory is successful, and the writer is recognized. This works because relatively few writings are involved, the memory store is small, and therefore the task is not difficult. It is less easy when two writings are somewhat similar; mistakes are then made.

Although there seems to be a scope for many writings that are recognizably different at a glance, there are far more writers than can be accommodated by the number of such variants. It follows, therefore, that the writings of many people must share a common overall appearance. A quick glance at overall appearance is as unreliable as a means of determining that two similar writings are by one person as it is when apparently different writings are taken to indicate two different writers.

There is far more scope within the detail of writing to separate different writers than there is in overall appearance. As discussed earlier in relation to block capitals, the method of construction and proportion of each individual letter can show enormous variation even within one general style of writing. The same considerations apply to cursive writing. Some letters can be constructed in several ways, although there are fewer variants than for block capitals, and all can be made by employing a wide range of proportions within and between the letters.

Methods of Construction and Proportion of Individual Letters

As an example of this, the letter *a* can be considered. A common way to construct the letter is to begin with the top of the curve and to draw a circle in a counterclockwise direction, following this with a down-stroke on the right-hand side. Another way is to begin the counterclockwise circle from the bottom and finish as before; a third is to write a circle and a right-hand vertical line separately as two strokes or joined by a bar at the top. Similar letters such as *d* and *g* afford the same variation in construction, also without basically altering the final shape of the letter. However, most different methods of construction or movement of the pen produce different shapes to the letter. In the case of the letters *b* and *r*, two or more methods of construction are taught. A letter *b* can be written either with its lower part made nearly circular and drawn in a clockwise direction after the down-stroke or by including a bowl-shaped curve with an opening at the top. A letter *r* can be written with a loop at the top or as a retraced down-stroke angled at the top toward the next letter. Other differences in pen movement that produce smaller differences in final shape occur in the direction in which the lower loops of letters like *f* and *y* are made. Having moved down, the pen can either turn to the left or to the right to produce a loop, or sharply change direction, making an angled tail rather than a loop.

A greater potential variation between writers is found in the proportions within individual letters. These will to some extent be dependent on how the letter has been made, but within any one method of construction, great differences can be found. Further differentiation can be caused by the connections between letters. In the letter *a* considered earlier, the first method of construction was a counterclockwise circle joined to a down-stroke on the right. This can be complicated by a connecting stroke from the previous letter or, if the letter begins the word or is the indefinite article, it can begin with a similar stroke, called a "lead-in" stroke.

From this apparently simple-shaped pattern, many variations can arise. First, the circular part of the letter *a* can be oval, angled upward, lengthwise, or at approximately 45° to the vertical. It can be a narrow oval or nearly circular. The connecting or lead-in stroke can be present or absent, it can join at an acute angle or with a small loop, or it can penetrate deeply down the right-hand side of the circle before retracing to begin the circle. The down-stroke on the right of the letter can be relatively tall or short, it can be separate from the beginning of the circle or touching it, it can end in a curve or angled tail on the way to the next letter, or it can end straight downward without either.

The letter *a* is a relatively simple letter, and others such as *h* and *k* provide a greater scope for variation between writers. The letter *h* is usually made in one movement—first the loop and then the lower part of the letter being written all in one stroke; there is little room for different pen motion here. The proportions, however, can be very different without any danger of the letter being unrecognizable as such. The loop can be nonexistent (merely a straight line), tall and thin, short and fat, or anything in between. It can be pear shaped, or straight on one side and more curved on the other. The height of the loop in relation to the height of the arch can be very different when made by different writers; the position of the bottom of the loop in relation to the beginning of the arch affords another means of variation, as does the shape of the arch. The arch can begin as an exact retrace of the down-stroke extending some way up the line, or it can separate at an early stage, producing an angle that may be narrow or wide. In this, as in all the alternatives indicated, there are intermediate possibilities.

All the other letters of the alphabet, both cursive capitals and lowercase letters, can be similarly analyzed. Other examples worth brief mention include the letter *i*, where the most simple feature anywhere in handwriting, the dot, can be surprisingly variable. Apart from its position, which can be high, low, to the left, or to the right, it may be written as a line, a small *v*, as a circle, or not at all. The letter *t* has a crossbar that can be variable in length, angle, height, and position relative to the upright part of the letter; sometimes it is written well away from the upright or drawn after completion of the letter instead of after the word, which is the taught sequence.

The ratio between the length of the loops and tails, sometimes called the upper and lower zones of the writing, and that of the main body of the letters (the middle zone), although often similar between different letters in the writing, shows wide variation between writers.

Variations within Words

In addition to the variations found within different examples of a single letter, short, frequently used words such as "of," "to," and "the" are sometimes written in a way different from that expected by comparison with their component letters found elsewhere in the text. There is room for variation between writers within words as well as within letters. The connections between letters can be short or long, so that the individual letters are close to each other or separated.

Not every letter in every word is necessarily connected to the next; some writers will connect only a few, say, no more than three letters, while others will write long words without any break. Some writers seem reluctant to join a certain letter of the alphabet to the next in the word, as if they had not learned to make a connection from that letter.

Disconnected Script

Another form of writing occasionally found is known as disconnected script. This can be regarded as occupying a position between block capital and cursive writings. Instead of writing letters of a cursive style joined together, the same forms can be written separately, a method that has the effect of slowing the writing but making it clear to read. The forms of the capital letters used are usually the same as that of the writer's block capital letters, and the small or lowercase letters match those of his cursive writing. There will be differences caused by the lack of connecting strokes, and sometimes a completely different form will be used for a particular letter, but often a considerable resemblance will be found between the lowercase letters of one person's detached script and those of the person's cursive writing.

Signatures

Signatures are usually another form of cursive writing, but need to be considered separately. A few people use their name written in block capitals as their signatures, but normally cursive writing is used. Generally, signatures can be divided into two types—those that closely resemble the normal cursive writing of the person and are really no more than the name written in his or her normal writing, and others where a distinctive mark is made, often barely readable or completely illegible.

Whatever the normal forms of the letters in the cursive writing of the subject may be, the signature must be considered separately. What is written is consciously chosen, whether it is the whole name, the first name and other initials, or just initials and the surname. The initials can be joined to each other or to the surname or separated, and the whole may have an underlying varying complexity.

When people are not used to writing much, it is quite possible that their signature is the piece of writing they most commonly perform, and so it may be of a higher standard of fluency than their other writings. This may sometimes give the impression that a piece of writing and the signature following it are by different hands. Sometimes, of course, this is the case; one person will write out a receipt or agreement or any other document and a second will sign it. If it is necessary to compare a signature with writing above it, care is needed because the writer may have adopted a special method of writing the person's signature, or may be more skillful at writing it.

Like other writings, a signature is subject to variation. No one can reproduce a signature exactly, like a printing process, and there are commonly wide variations found in the output of one person. As with other writings, some people are quite consistent and others extremely variable. Signatures can be made in a variety of different places; some are comfortable and therefore conducive to the most natural results. In others, where there is difficulty in writing, the results may be somewhat different. The significance of these differences is discussed in the next chapter.

Layout

Apart from the writing itself, there are other elements of a written page that vary from person to person but tend to remain constant in the output of one person. The way the writing is arranged on the page, the size of gaps between words and lines, the use of punctuation marks, the employment of margins either side of the text, and the separation of paragraphs and where they begin all give a scope for variation between writers. Special documents, for instance, envelopes and checks, provide further areas of diversity between writers. The address written on an envelope can begin near the top or further down; the lines of writing can be well spaced or not and can be staggered. Commas or periods may be present at the ends of lines or after a house number. Parts of checks can be written in many combinations of methods. The way chosen to write the date and the money amount in writing and figures, the position of the payee's name, and other features can vary greatly.

Such layout factors tend to remain consistent even when deliberate changes are made in writing style and can add evidence to that gained from the study of the writing itself.

Variations within the Writings of One Person

Reference has been briefly made to the variations found within the writing of one person, especially differences in overall appearance due to speed of writing and other factors. In these conditions, much of the detail described above will remain unchanged, and characteristic or unusual features will still be found. However, no writer is so consistent that each example of a particular letter of the alphabet is so similar to the same letter written elsewhere that it could be exactly superimposed on it as could two printed letters. For instance, to say that the letter *h* when it occurs several times has a tall, thin, pear-shaped loop and a narrow arch is to give a verbal description to a number of letters *h* that are not in themselves identical. Nevertheless, they all differ from one described as without a loop and with a wide arch. This is typical of most letters in a sample of handwriting. Although not identical to each other, they fall within a range that is relatively small and excludes many other variants for this letter.

Often, samples of writing from two people will include several letters that are indistinguishable. To put it another way, the variations of two samples of a particular letter can occupy the same range partly or completely. In some writings, more than a few letters can show this similarity, but there are always some letters that are consistently different.

Although the variations found in the writings of one person can be contained within a defined range for each letter, there are occasionally odd examples that do not fall within the range. Accidental events, caused perhaps by a jolting of the pen, difficulties of control near the bottom of the page, starting to write a different letter, or isolated examples for which there is no apparent reason can result in a letter being written sufficiently differently from all the others to be outside their range. Such differences should not be taken as evidence of another writer. However, if the range within which all or nearly all of the examples of a particular sample fall differs from the range of variation of the same letter in another sample, this is evidence that the samples may be by different writers. Sometimes, these differences, called consistent differences, are quite small, but their reproducibility within each sample, and their consistency in being different between the samples is of greater significance than a larger difference of a single example that may well be one-off and atypical. It is rare to find only one example of a consistent difference between two samples of writing. Normally, there will be far more than one in the writings of two people, and none in the natural writings of one person.

Use of Different Letter Forms by One Writer

As well as variations found within individual forms of letters, it is not infrequently found that a writer will use more than one separate form of a particular letter. Perhaps both forms of the letter *b* described earlier may be found in a single sample of the writing of one person. Other examples of this use of different forms can occur in capital letters, where one writer may use both block capital and cursive capital forms apparently at random. Similar use of two or even more forms can occur with other letters, in some cases depending on their position in a word. One form may be found consistently only at the end of a word, while the other form is found in the middle or at the beginning of words. Where two forms occur, there will be little relationship between them, and they are best regarded as different letters and would be expected to be seen in all substantial amounts of writing by that person. As with other letters, each will have a range of variation within the examples present that will be different from the ranges of the same letters made by most other people. However, most writers do use only one form for most letters.

Personal and Style Characteristics

In the variations found between the writings of different people, some features occur reasonably frequently and others only rarely. Some people introduce into their writing features that are very unusual. These are sometimes called personal characteristics, indicating that they characterize or are a means to distinguish the writings of one person from those of others. This is largely true in that, because of their uncommonness, they are unlikely to be found in the writing of another person picked at random.

In the writings of many other people, especially those who do not have opportunity or need to write very often, there may not be much progression from the standard form originally learned. Many of the features found in their writings have a common source in the copybook of the style of writing taught. They are therefore not unusual and are likely to be found in combination with other such features that also have the same origin. These are characteristics of a style rather than of the method of an individual and are therefore sometimes called "style" characteristics.

The Significance of Variations between Writers

All of these considerations, in addition to overall factors such as size, slope, line quality, and smoothness of curvature, provide an enormous potential to separate the block capital and cursive writings of one person from those of another (Figures 2.3 and 2.4). What makes this possible is the fact that with

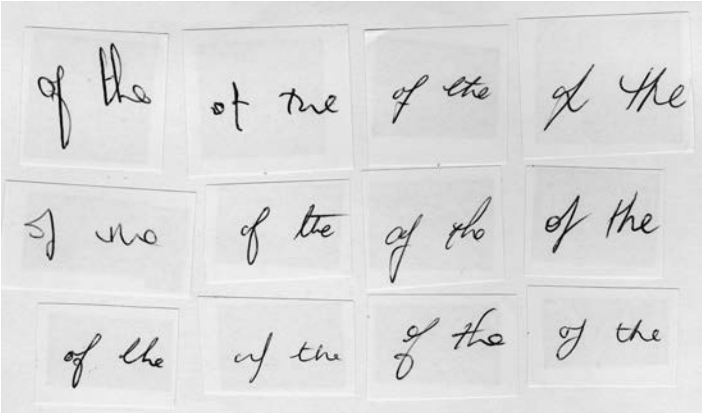
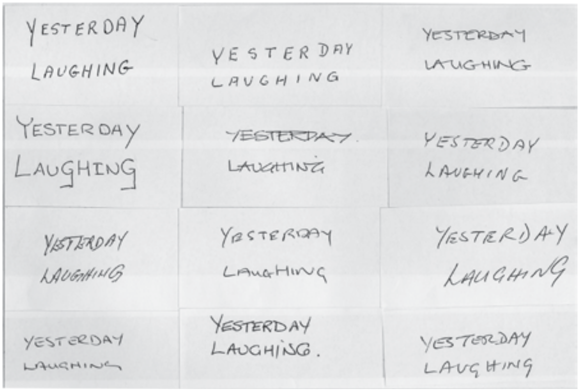


Figure 2.3 Some examples of the words "of" and "the" written by different writers. Note the wide variation in the proportions of the letters.

(a)



(b)

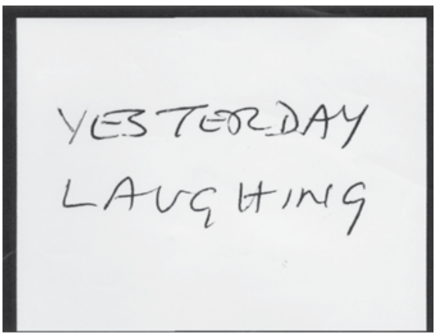


Figure 2.4 (a) Two words written by 12 different writers. Different methods of construction and proportions among letters and between each written word can be observed. (b) An enlargement of one of the examples shown in Figure 2.4a. Note the connecting lines where the pen has not completely lifted in the letters E and H.

so many variables available in every letter, and so many letters available for comparison between the writings of any two people, there is no practical possibility that one will resemble the other in every respect. Of course, such a coincidence is in theory possible, but to encounter it in practice can safely be discounted. However, this states the ideal position and refers to writings of a person as a whole. To say, then, that any one individual has a uniquely personal method of writing may be true, but to say that every piece of writing made by that person could not be matched by another person is not. How true this is for any one piece of writing depends on the amount of material present and how unusual it is. Provided that a sufficient amount of material is present, the combination of features used by one person in his or her writing will be sufficiently different from the combination of features of any other person that the finding of a chance match would be extremely unlikely. If the amount of writing is smaller, the probability of coincidental match will be greater.

How these factors are considered in the comparison of writings for forensic purposes is dealt with in more detail in Chapter 4.

Spelling Mistakes, Text Analysis, and Other Variables

When writings of different people are studied, much can be gained from aspects other than those of the writing and its layout on the page. Some people are not good at spelling correctly, and errors are found in their writings. Similar errors may occur in questioned writings suspected of having been written by them. This rather obvious feature is often given great weight by the layperson, but those who examine documents regularly find that certain mistakes are so common as to provide little significant evidence. Words such as "forty" and "ninety" are often spelled wrongly, and the document examiner is more likely to warn that too much emphasis should not be put on them rather than pointing them out as similarities of importance. Generally, however, practitioners in forensic handwriting comparison do not regard themselves as experts in the frequency of occurrence of misspellings, and are therefore not inclined to comment on them. In court, the jury may be told that the way certain words are spelled has played no part in the conclusions reached from a comparison of handwritings, and any evidence they choose to elicit from this is over and above that obtained from the writing. In taking into account the spelling of a word, it should be borne in mind that misspellings are an obvious feature to copy when attempting to simulate people's writing and also that people can suddenly learn to spell the word, and the wrong spelling will then suddenly disappear.

The analysis of the textual style may also be of value but is rarely attempted by document examiners. There is in certain cases much to be obtained from this by people who specialize in the analysis of text. The stylistic approach to comparing writings requires reasonably large samples but is independent of the medium in which it is written; handwriting, for instance, can be compared with printed text. Factors considered are length of sentence, ratio of sentence lengths, verb/adjective ratio, use of certain words ("however," for instance), and the ratio of syllables to words. Proper evaluation of such features can provide useful evidence in certain circumstances and has been used when statements of defendants have been challenged. For more details on forensic linguistics, see Coultard et al.[4]

Non-Roman Scripts

The principles described above in relation to writings in English in roman script also apply to writings in other languages and scripts. Whether the writings are made from right to left or left to right, whether they are based on phonetics or on characters representing words rather than letters, there are variations within and between writers, and significant evidence can be drawn from these.

In writings made in non-roman scripts that also use a phonetic alphabet, variations occur within and between writers in the same way as they do in roman scripts. Some alphabets have a greater capacity for variation than others. In Arabic script writings, some letters are distinguished from each other by the number of dots, between one and three, above or below a feature common to all of them. There is, however, a difference between the same letter written on its own or at the beginning, end, or middle of any group of letters; such a group may not necessarily be a word. Consequently, a large amount of comparable material is necessary in these writings.

In Chinese, words are written as separate characters, not phonetically. The characters are built up from eight different forms of stroke, each of which is shaded, that is, made with a gradually changing width of the writing line. In traditional writing, this is made with a brush. But even with ballpoint pens, some shading is possible and can be used as a method of distinguishing between two writers. As in other scripts, the method of construction—the order in which strokes are made—plays an important part in the distinction of writings of different people, but to a greater extent because of the complexity of the written characters. Differences in ratio between width and height are also important, as are the individual strokes themselves. These may be shaded or made with pen emphasis, giving a wedge-shaped beginning or end of a line. Variations from what should be symmetrical or parallel strokes are also found in different degrees, and so are slope and spacing of characters. There is scope for spelling errors because the same monosyllabic sound may be represented by many different characters, and the writer may not be aware of the correct one to use. The human condition of individuality and unmachine-like variability applies across national and racial boundaries.[5–10]

Classification of Handwritings

Certain features that are present in some writings but not in others can be used to place writings in groups that contain them and differentiate them from other groups that do not. The advantages of such classification of writings of different people are twofold. First, some indication of the frequency of occurrence of certain features can be measured. Second, a system can be used with a collection of handwritings to retrieve a matching writing without searching through every example in the collection.

Such classification is not easy. Most of the features that distinguish one writer from another, though clearly different in the writings of two people, are continuously variable through the population. It is therefore difficult to define a line of separation, and this problem is increased because of the variability found within the writings of one person. The natural range of variability of one writer may span the chosen dividing line.

Despite these problems, several systems for the classification of writings have been devised, including one that has been in use in Germany for many years. This is based on overall features common to different letters of the alphabet rather than more detailed examination of the letters. Similarly, systems for classification of stolen checks, which are based largely on features of the word "pounds," have been used in the United Kingdom. The method of construction of block capital letters was used in another method of classification that was developed in the Metropolitan Police Forensic Science Laboratory in London. The advantages of this method were that the differences between writings are clear-cut and unambiguous, and that the features used tend to remain consistent between writers. This system provided useful information about the frequency of occurrence of different methods of construction.

Other measurements have been made with cursive writing and signatures.[11–13] Generally, however, there has not been enough quantitative data collected to have much impact on the work of the document examiner, who relies more on his or her own observations and experience.

Pattern Recognition Techniques

The development of methods to read handwriting by machine has led to the application of these techniques to distinguish between the writings of different people. Computer-based pattern recognition methods are complicated, requiring specialist knowledge. For example, heights of upper loops and the areas within them can be compared and measured and data provided. Similarly, areas within circular letters and angularity can be calculated.

These methods have not yet entered the area of forensic document examination to any great extent. It appears that they will provide a method of retrieval of a similar writing from a large number of samples in a collection; in Germany, this has already begun. In the United Kingdom, research has been carried out into the use of such methods to authenticate signatures at points of sale. Considerable work has also been done at the Center of Excellence for Document Analysis & Recognition at the University at Buffalo, part of the State University of New York. Further information about this work can be found via the university website at www.buffalo.edu. As most legal systems require that there be an individual responsible for any evidence given, it seems unlikely that evidence in courts of law will be based solely on pattern recognition techniques any time soon. However, their use as a tool in handwriting examinations is likely to increase.[14]

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Handwriting
Accidental and Deliberate Modification

3

Introduction

In the previous chapter, natural handwriting was described. The variations, and some of their causes, between the writings of different people and within the handwriting of an individual were outlined. The subject is further complicated by accidental and deliberate modification, and in this chapter, these complications are discussed. In the next chapter, the conclusions that can be properly drawn from the examination and comparison of two or more handwritings in the light of this background will be considered.

Accidental Variation of Handwriting

The variations within the writings of one person, mentioned in the previous chapter, occur however hard the writer tries to avoid them. A well-practiced calligrapher used to writing in a very consistent artistic hand may achieve a result where each example of any letter is nearly identical to all the other examples of the same letter, but no two will be exactly the same. A neat, careful writer will produce a consistency not far short of that of the calligrapher, but for most people, even in ideal circumstances, their writings will show quite noticeable differences between different examples of the same letter of the alphabet.

Writing conditions in the day-to-day course of business are often not ideal. They can be impaired by difficulties produced by physical causes, such as the quality of the pen or the writing surface; by the position of the writer, who may be operating in an abnormal position; or by the health (in the broadest sense of the word) of the writer.

Writing Instruments

A wide variety of pens is now available, ranging from those with wide nibs using water-based inks, to pens that use a porous material such as felt or compressed fibers to apply a similar ink to the paper surface, to ballpoint pens, where a rotating ball rolls either a water-based ink, or, most commonly of all, a glycol-based paste onto the paper. Despite this variety of instruments, little difference is found in the writings of one person when using different types of pens. This is because nearly all pens now write from a single point source. This applies to a pointed fiber pen, a ball pen, or even to a fountain pen, which is tipped with a blob of hard metal rounded to an approximately spherical shape. When a broad nib or a wide fiber-tipped or felt pen is used, there may be differences produced that are due to the greater difficulty in moving a wide pen upward at right angles to its width, but with most modern writing instruments, the differences in friction that occur with different pens and paper surfaces are hardly noticeable. Of course, a defective nib, or a very rough surface on which the paper is placed, will affect writing. Broken pen nibs, deformed fiber points, or a ball not rotating properly in its housing can all result in uneven flow of ink onto the paper. The line may be uneven both in width and along its length. In addition, the difficulty of guiding a point that is no longer smooth across the paper surface will affect the intended movement of the pen, particularly in the ease of changing direction. This may force the writer to lift the pen more often than normal, and will therefore give the appearance of a different method of construction. An extreme case of this was found when writing was made with a ballpoint pen on a plaster wall. The writing was made with the pen pointing upward, and this cut off the flow of ink; many ballpoint pens depend on gravity to feed the ink to the ball. When the ink ceased to flow, the writing was continued by making a deep impression in the plaster surface. This transferred metal from the ball housing to the wall like a pencil depositing graphite by friction, and it gave the same appearance as a pencil. The effect on the writer was to force him to reduce each letter to a series of separate strokes with no sharp angles or curves. In less extreme cases of unusually high resistance to movement of the pen, similar modifications of the writing are found.

When paper is placed on a rough surface, the coarseness of the background will affect the writing line. Instead of a smooth-flowing line, there is instead a line that is broken up by the irregularity of the underlying surface. If an unplaned wood surface is under the paper, a regular pattern following the grain of the wood is formed. As the pen runs over the raised ridges, more ink is left on the paper, and when it passes over the troughs, less is deposited. This effect can be confused with that found in simulated writings (to be discussed later), but the regularity of the unevenness is a good indication of such a background surface effect.

A very glossy paper can result in poor take-up of ink, giving a similar appearance to that when a poor-quality pen is used, but the writing line can often be seen as an uninked impression. In such cases, double pen lines may be found because the writer tries to correct an unsuccessful attempt to put ink on the paper. This, too, can be confused with an attempt to simulate writing. The confusion may be increased if differences caused by difficulties of pen control are also found. In the act of writing, the friction of pen on paper is allowed for. On a shiny surface, the friction will be less, and the pen may be more difficult to guide in the intended path. This results in small differences from the normal writing.

Thick-nibbed fiber or felt-tipped pens have little effect on the actions of the writer, but the examiner may find difficulty in establishing the pen movement from his or her examination of the writing.

Writing Position

When writings are made in awkward positions such as standing with a pen in one hand and a notebook in the other, the control of the pen is less than when writing is made in ideal conditions. Examples of this may occur when a registered or recorded delivery is signed for at the door at the request of the mail carrier, although, in many cases, these signatures are now recorded electronically. Again, a delivery of goods to a factory or building site may be receipted by signature of the delivery note resting on anything conveniently available. Transactions completed or notes made in moving vehicles, aircraft, or ships may be the subject of an enquiry that requires a handwriting comparison. The writings, too, may show evidence of difficulty of position of the writer or the paper.[1]

However, the effects are not always very great. Instead of a letter being carefully made with the normal degree of retracing along a line, the retrace will be less exact; for instance, instead of a letter *a* being made with a reasonably closed circle, there may be a gap where the top of the circle and the right-hand upright do not meet. (The effect of apparently stretching the line of writing and opening enclosed areas and retraced lines is not unlike the effect of fast writing.) In addition, accidental effects occur. Odd pen movements resulting in poorly shaped loops or strokes that are too long are caused by lack of consistency in pen control. Difficult writing conditions can be variable, so the quality of the writing will also be variable. Therefore, in these conditions, some words will appear quite normal, while others will be considerably deformed.

The position of the writing itself, rather than that of the writer, can affect the result. This is most likely when writing or a signature is made in a restricted space, for instance, at the bottom of a page. Basic features, such as the method of construction of letters, are unlikely to be affected by such difficulties. The subconscious act of directing a pen in a particular direction is too ingrained to be easily deflected, but proportions of letters and words might be modified.

Other examples of writing in abnormal conditions are found on walls and other vertical surfaces, often made with different writing media such as chalk or brushes. These constraints will introduce some differences from writings made in more normal situations. The greatest differences are likely to be found in an increase in the number of strokes used to form individual letters due to a greater degree of friction between the writing instrument and the surface, but the overall method of construction and relative proportions within the letters and words tend not to change, apart from greater variation in the shapes of loops.

Health of Writer

The health of the writer will affect the writing. Some conditions result in mental disorder, others produce a disability in the hand, while others cause a weakness that renders proper control impossible. The examination of patients' writing has been used to diagnose certain illnesses both physical and mental, but the study of the connection between illness and handwriting is too large a subject to be dealt with in detail in this book. However, in many cases requiring the examination of handwriting, illness or the effect of drugs or alcohol plays a part. Some signatures on disputed wills either are written at a time of severe illness or are claimed to be so.

Comparison of these signatures with those written in good health will reveal great differences either because of illness or because a different writer has been involved. It is important to consider the two possibilities.

Studies made on the writings of the elderly or people who have a debilitating disease show that the effects depend on the degree of infirmity as well as the disease. Some complaints, such as Parkinson's disease, produce a tremor; others, such as arthritis, affect the ability to hold the pen or to move the hand or fingers easily. Impairment of eyesight will also affect a person's writing. The effects found in the writings of people so afflicted are fairly predictable. Tremor of the hand shows up in an even oscillation of the writing line, while poor coordination produces lines that are not smoothly curved, misplaced strokes, poorly joined circles, and trailing lines instead of pen lifts. There is also a consistency in the writing. Tremor found in one part of the writing will usually be found throughout, and lack of control will be even within the writing. An exception occurs on those occasions when the writer becomes tired during the period of writing and the quality worsens.

Although normally consistent with writing made at a single sitting, poor quality due to ill health can change over an extended period. Some illnesses, especially those associated with age, worsen, and a steady deterioration can be seen in the writings of a patient as time passes. In some cases, this may be arrested or reversed as the use of drugs controls the symptoms. When dealing with such cases, it can be useful to have information from the medical notes of the writer in order fully to understand the effects the medical condition is having on the person's ability to control a writing instrument. An example of this was where the medical notes stated that a person's Parkinsonism was causing an intermittent tremor that could have been mistaken for the tremor found in simulation. Recent work by Dziedzic[1] has investigated how writing in a prone position, such as might be encountered in death-bed wills, affects writing quality. In all cases, but particularly those involving infirmity, it is very important to ensure control samples are contemporaneous with the writing in question and preferably span a range of dates during which time the writing could have been made.

Guided Hand Signatures

In cases of extreme illness, signatures are sometimes made with the assistance of another person holding the hand of the signer and guiding it. In some cases, the pen may be in the hand of the designated writer, but little or nothing of the natural habits, which at one time controlled the movement of the writing line, are left. There will, therefore, be no evidence that the person whose hand was guided had anything to do with the writing of the signature. If the hand is entirely limp, the writing style of the person guiding it will be found in the signature.

Such signatures may be constructed from a number of ill-formed and separated strokes or may be in the fairly well-formed writing of the assistant. There is little to be gained from any comparison with the original signatures of the individual that were made when in good health.

In other cases where the assistant merely supports the arm, there is little departure from the normal signature. In between the two extremes, the resultant signature could be a mixture of the writings of both the writer and the helper. Here, there is a tendency to find greater pressure on the paper, a poor line quality, and change in the direction of writing. In addition, accidental features quite different from the normal signature may be found.

The consideration as to whether a signature has been made by a guided hand are more likely to occur when a simulation is claimed to differ from the "real" signature because it was made with assistance. The distinction between the two methods of making a signature different from the normal signature of the writer is, therefore, of great importance. Those features, described later, that are normally found in a simulated signature, made by free hand or tracing, are clearly distinguished from those of the guided-hand signature.[2]

Drugs and Alcohol

The taking of drugs in therapeutic quantities will affect the symptoms of many diseases and enable the sufferer to write with fluency and control that the person would not have without them. This has been found with treatment of diabetes, Parkinson's disease, and states of tension relieved by tranquilizers.

The effect of drug addiction on handwriting has also been researched. Under the influence of narcotics and alcohol, writing is modified as muscular control deteriorates. Studies of controlled subjects have indicated that the effects are not the same for each person. In general, however, the writing becomes larger and less well-formed and coordinated. The method of construction and relative proportions remain the same, but the latter can be modified by the enlargement and distortion. The writing of addicts and alcoholics will be affected by high concentrations of the drug and also by the discomfort caused by its withdrawal. The most natural writing is found when a state of well-being is induced by a lower concentration of the drug.

Impairment of Vision

Impairment of vision also affects writing. Writing can still be made even with complete blindness, but the effect is to run lines together, or otherwise to misplace the writing line. Sometimes a ruler or other straight edge may be used as a guide line. This is easily discernible in the writing, with horizontal lines appearing at the bottom of many of the letters and lower loops absent. The use of a straight edge to keep writing in place is not confined to poorly sighted writers but is found elsewhere, often where it is necessary to place words and figures neatly into a limited space.

A further feature found in the writings of the visually impaired is that some obvious errors that a sighted person would have noticed remain uncorrected. For instance, the splitting of the signature into two halves, both formed in the right way but not in the correct alignment to each other because the pen had to be taken off the paper, then returned to it in a different position.

Deliberate Variation of Handwriting

Handwriting, then, can be abnormally varied by many conditions without the writer specifically giving thought to it. The acquired ability to express ideas by writing words made up of individual letters is exploited, with little consideration about how it is done or what it looks like, except for a general need for writing to be readable and perhaps attractive. In normal writing, detail is relegated to the subconscious, and attention is not paid to every movement of the pen; writing is a well-formed habit in most cases, not a conscious action.

However, deliberate alteration of writing occurs on many occasions both for amusement and for deceit. Documents bearing such writings are frequently involved in both the criminal and civil courts.

These unnatural writings, where deliberation has been employed, can be conveniently divided into two classes. The two divisions are (1) the disguise of writing to make it appear not to be by the person who wrote it and (2) the simulation of the writing of another person. As in any such division, the border may not always be clear; copying the writing of another person effectively disguises the style of the copier.

Disguised Writings

Each February, many anonymous communications are sent by mail. The object is for the recipient to be faced with the problem of identifying the sender of a St. Valentine's Day card. However, similar deception is attempted in many other circumstances for less innocent purposes. Vicious threatening letters, obscene missives, and explosive devices are occasionally sent through the mail. Notes demanding money are passed across bank counters. In many of these cases, attempts are made to make the writings less characteristic of their writers. Samples of writing given for comparison purposes are also frequently disguised.

The most obvious feature of the writing of any person is its overall appearance. How large it is and how it slants are features immediately noticeable without close examination. Therefore, the most likely move to disguise is to modify the appearance by changing the size or the slope of the writing. The effect can be to alter the apparent style quite dramatically. A pronounced forward slant is clearly different from a backward one when all the writing on a page is seen at a glance. Similarly, small, cramped writing filling a page gives a different overall effect from that given by widely spaced, large, open letters. In the previous chapter, the detail found in individual letters was discussed. This detail, produced subconsciously, will be little affected by changes in slope or size. The method of writing each letter and the general proportions used as a matter of habit will remain largely unchanged. Although small differences may be introduced to accommodate the deliberate alteration, not much will change. For instance, the ratio between the height of loops and the middle zone of the writing tends to remain much the same.

However, disguisers may go a stage further and make deliberate amendments to the shape of loops or proportions of letters. They may also alter the features that they believe are most characteristic of their own writing or introduce new grotesque letterforms that are totally unlike anything they normally use. The wrong hand may be used to write a disguised passage, the left hand for a right-handed writer, and vice versa. This normally results in a poorly controlled, untidy, and irregular effect, larger than the writing made with the usual hand.

Another method of disguise is, of course, to use a totally different form of script. Sometimes block capital letters will be employed, but this is not so much a change of handwriting as a change of writing method. Similarly, lowercase unjoined letters might be used, or a mixture of both. Other methods include writing with less skill than is usual. A skillful writer can introduce evidence of lack of ability, imitating the poor quality and hesitancy of a near-illiterate person. Any writer can revert to the basic copybook method that was originally taught. The person may write slowly, deliberately, and precisely, remembering each form and reproducing it consistently.

People who have more than one method of cursive writing can use the one not familiar to the recipient. This hardly counts as disguise in that both forms of writing can be made naturally, but the intention may be the same. Some people find little difficulty in achieving a different method, but this is exceptional and contrasts with the problems encountered by most people, who do not have such an ability.

Difficulties of Disguising Writing

The subconscious method of writing each letter is so ingrained that the conscious effort to change it is great. Less effort is required if only the slope or size is altered, but even then, the rhythm that comes from habit and gives a consistent angle to the writing will not be there. This means that the newly chosen angle of the disguise may lack consistency. Some parts will slope more than others, and some parts may actually revert to the natural slant.

The same inconsistencies occur when differences of detail are introduced. For instance, in a particular case, an anonymous letter was written in a disguised hand. Not only was the slope reversed, but the lower loops of the letters *g* and *y* were made with a double loop in the form of an 8. This contrasted with the single loops of the normal writing of the writer. However, not only were there some examples where the new form had been forgotten, but some had been written first as single loops and then retouched with extra strokes in an attempt to maintain the consistency of the different form. This is typical of disguised writing. Lapses of concentration cause reversion to the natural method.

As with every other human activity, the ability to disguise varies with the individual. Some people are good at it, consistently changing many features, while others find it nearly impossible to make any appreciable change from their natural method. As in other activities, practice will no doubt enable better results to be obtained. A person determined to disguise his handwriting could spend days or weeks perfecting a different style that would have little in common with his normal method. Fortunately, this is rare. People committing crimes or other forms of deceit normally do not go to so much trouble. If the amount of writing is of reasonable quantity, many of the features of their normal handwritings will remain, but if only a few words are written, it is not difficult to maintain concentration sufficiently.

In the investigation of a crime, it is common for the suspect to be asked for samples of writing. The opportunity for disguise is frequently seized, and the samples are written using a method very different from what is normal. This possibility must be considered when such samples are taken and again when they are used as comparison material. This will be dealt with more fully later.

Block capital writings are not so often disguised. Perhaps the common belief that they cannot be identified and are not characteristic of their writer leads people to regard it as unnecessary. When disguise is used, it tends to take the form of carefully written copybook letters, each letter made in as many different strokes as possible, or of letters ornamented with extra and superfluous serifs.

Disguised Signatures

Some disguises encountered in criminal investigation are found in signatures. A common method of fraud is to sign a document and then disclaim the signature. This may occur in, for example, applications for loans, especially if the loan is secured on the applicant's home. Rather than attempting to claim that a normal-looking signature is a perfect copy, the person committing fraud will introduce differences. These will often be sufficiently noticeable to be pointed out later when the signature is denied. "I never write a *J* like that" is a typical remark. Much of the signature will remain unaffected, but the more obvious features, like the capital letters, will be modified. It will be necessary in many cases to avoid too great a departure from the normal signature because the recipient may compare the result with an identifying signature on a credit card, driver's license, or other document.

A common result of this ploy, therefore, is a signature written with normal fluency and with good match in detail of letter formation but with some clear discrepancies, especially in capitals. This does not present a great problem for the document examiner. When considering the possibility of simulation by another person, the combination of a close match in detail together with obvious differences would be considered inconsistent and inexplicable. The other alternative, self-forgery, is far more plausible.

This is not the only way of writing a signature designed to be denied later. If no comparison is to be made with a standard, a completely different design can be chosen so that, when it is challenged later, the signatory can claim that it was not them but someone impersonating them. It is not difficult to change a small amount of writing completely so that it shows little resemblance to the normal. This can present a problem. Often no evidence of the normal method of the writer remains, and there is no indication of them having made the signature. On other occasions, the signature is reduced to a hardly readable scrawl. In these, movements of the pen corresponding to those of the normal signature of the writer are sometimes found. This would be unlikely to occur if another writer had copied the genuine signature; the attempt is likely to match in overall appearance rather than in detail.

A further method, one rarely found, is for the self-forger to produce what another person would when simulating a signature. The same features, described later, that are found in a drawn or traced signature can be introduced deliberately into one's own signature. In a survey carried out in Germany for research purposes it was found that a small proportion of people asked to disguise their signatures chose this method.[3]

Simulated Writings

There are two main methods of simulating the writing of another person. One is to "draw" the writing as if one were drawing an object. This results in a freehand copy or simulation, so called because the hand is free from restraints such as previously written guide lines. The second method is to use such guide lines and to trace over them with a writing instrument. This is known as a traced copy or simulation. Although the two methods are basically different, an inaccurate following of a signature may be similar to an attempt to draw it. There is, therefore, a continuously variable range between the two methods. Normally, however, the choice is made between a drawing or a carefully followed tracing.

The result of both methods is likely to be a forgery—writing that deceives. However, the word "forgery" implies intent to deceive and is best avoided when describing simulated writings, whether freehand or traced copies. They may have been written by another without any felonious intent and in full knowledge of the person whose writing has been copied. On the other hand, a signature written by another without any attempt to copy the normal style of its owner will be a forgery if it is made with intent to deceive.

Writing, as has been seen earlier, is not uniform and varies both between different persons and within the writing of one person. The quality is also a variable factor. To copy writing successfully does not require a precise match, because two pieces of writing by one person will not be precisely the same. It is necessary to place the result somewhere in the range of variation of the writing being simulated so that it is thought to be the same writing.

Freehand Simulation

Freehand simulations can be made of signatures or of larger amounts of writing, but the former is more common. The signature appears to have been used as a means of authentication since the sixteenth century. Even then, the danger of simulation was recognized, and extra flourishes unnecessary for reading the name were added to minimize the danger. The same practice is found today. Some people will introduce elaborate rubrics, which pose an extra problem for the forger.

When a signature is copied, the copier needs to reproduce its overall appearance sufficiently well to deceive the person who must check its authenticity. This is all that is needed. The bank clerk or car rental clerk will glance at both the signature presented and that on the credit card or driver's license and be satisfied. Little attempt is made, especially if the counter is busy, to examine it closely, so there is little need to make a closely matching simulation. If greater care is required for the deception, more effort is needed to produce a better copy.

The problem of achieving a good copy of a well-formed and flowing signature is that two conditions must be met: first, accuracy in shape and proportion within the signature and second, smoothness of line. Either one is not too difficult to manage, but, for most people, to satisfy both is nearly impossible. Normally, a copy is made either by writing slowly to achieve accuracy or by writing rapidly so that more fluency is obtained.

Slowly Made Simulations

Accuracy is best achieved by writing carefully and slowly, but this makes writing with smoothly graduating curves and loops difficult. Instead of the loops turning gradually from a lesser to a greater curvature, giving a smooth appearance, they change more abruptly with greater angularity.

When writing is made naturally, the pressure applied to the paper is not consistent. Some lines are made quickly and the pen hardly touches the surface, while others, where more change of direction is required, are made with more weight. When the pen is lifted to begin the next word, the pressure is progressively reduced and the end of the line tails off gradually. In trying to produce a careful and slowly made freehand copy, such variations in pressure are difficult to reproduce. Because they arise from the speed of natural movement, they cannot be produced when the hand is moving slowly and is consciously controlled to imitate an unfamiliar pattern. Instead, the slowly moving pen is maintained at a more constant pressure on the paper, the written line is therefore more even in width, and its end is not tapered, but blunt.

Despite the care taken to copy accurately, a drawn simulation is often outside the range of variation of the genuine signatures in the shape of some or even all of the letters. The overall proportions of a signature may be wrong, and the relative proportion of letters and the spacing between initials may not be reproduced accurately. The shapes of loops are often difficult to imitate, and so are complex underlinings and other rubrics. If several signatures are in question, then the range of variation may be different from the range in genuine signatures, and indeed may not exhibit the full range of which the writer is capable. A forger usually only has one model from which to simulate and will not appreciate the range of variation shown.

In natural writing, the pen is likely to write most if not all of a single word without leaving the paper. This is also the case for signatures; individual letters or words are made in one line or else a stop is made regularly in the same place. When a signature is being copied, more accuracy is achieved when the pen travels for a shorter distance. The signature is then completed in more strokes than were present in the original, and breaks are found in the writing line. It is not always easy to determine whether this has occurred, but under the microscope, using a magnification of about 20–40×, breaks in the line can usually be detected. When a genuine signature is "drawn" to produce a simulation, the form will be reproduced as accurately as possible, but little attention may be paid to how the signature was constructed: how the pen moved to form the letters and to join them. The copy may therefore include several letters made in the wrong way. This is important evidence to indicate that simulation has taken place; such differences in letter or word construction are most unlikely to have been introduced by the genuine writer.

The drawing of a signature, as opposed to writing, naturally gives rise to the possibility that the forger may choose to copy it upside down. Whether this is an advantage is doubtful, but it can happen. Similarly, a signature in Arabic or other scripts written from right to left may be copied by writing from left to right. Indications of lines made in the wrong direction provide conclusive evidence that the signature is not natural.

When a signature is copied, or more commonly when larger amounts of writing are simulated, mistakes are made, noticed, and corrected. This means, for instance, that an addition may be made to close a gap that should not be there at the top of the circle in a letter *a*, *d*, or *g*. In other cases, the length of the staff of a *t* or the loop of another letter might be adjusted by the addition of the necessary connecting stroke. This is known as "patching."

Another error occasionally made by a person copying a signature is to mistake one letter for another in a signature he is trying to reproduce. This will occur when the letters of the genuine signature are not clearly identifiable. The resulting copy may include obviously readable letters that do not occur in the name, the copier having erroneously thought that they were there.

Simulations of Poorly Made Signatures

To make a freehand copy, then, is usually not an easy task. The difficulty is considerably reduced when the signature being copied is short, slowly written, and rather more variable than usual. The poor line quality of a copy will not be very different from the model, and the task of making the copy fall into the range shown by the genuine signatures will not be too difficult. Copied signatures of this type may be nearly indistinguishable from the genuine.

Coincidental Matches and Signatures

If the target signature contains few personal characteristics and is essentially an ordinary piece of writing written in a copybook style coincidentally similar to that of the forger, then all the forger would need to do would be to write the name in his or her own style, and the detection of the simulation will be very difficult. Simple signatures, for this reason, often result in an inconclusive opinion. Work has been carried out on dynamic signatures and suggests that, if the genuine and forger's writings are coincidentally similar, then the job of simulating is made easier.[4] Conversely, if the signature is highly personalized, containing indistinct letters and extra flourishes, then a coincidental match can usually be eliminated; either the signature is genuine, or it is a deliberate attempt at simulation.

Rapidly Made Simulations

People vary greatly in their ability to simulate a signature by producing a freehand drawing.[5] Some improve considerably with practice, but others are never able to make a good copy. Unfortunately, it is not necessary to acquire any great skill in the art of imitating the writing of another person to obtain the benefit of forgery because the person, such as a shopkeeper, who has the task of verifying a signature on a document will usually give it only a cursory glance. In such transactions, it may be necessary for the forger to produce his or her simulation in front of the person receiving it. He or she cannot sit down and carefully copy from a model, but has to learn the pattern first and then quickly write it, usually in a different place. This leads to a greater divergence from the genuine signature, but the result will usually pass the brief examination given.

When such signatures are written, and the same applies to larger amounts of writing, inaccuracy rather than poor line quality is the most likely result. The problem of remembering all the features of the signature being forged, or observing them at the time of writing, is usually too great to enable a signature to be written within the range of variation of the genuine signatures. Practice may improve the prospects of making a good copy close to that range, but it is unlikely to enable the copier to avoid inaccuracies, especially in the relative heights of letters, spacing between capitals, and shapes of loops. In addition, the method of construction of the model signature or of its individual letters may not be noticed or not reproduced, and will provide clear evidence that the copy is not genuine (Figure 3.1).

Traced Signatures

Tracing is widely used as a method of simulating signatures, especially when the object is to reproduce it as exactly as possible. In some cases, writing apart from signatures is traced, but to do so requires the possession of sufficient writing from which to trace the wording required for the deception.

To trace a signature, it is necessary that the shape of the model to be copied be placed in the right position on the appropriate document. This can be done in a number of ways. A piece of carbon paper can be placed on the document and the signature to be copied placed over it. Light pressure of a pen following the line of the signature will produce a carbon impression on

Figure 3.1 On the right-hand side of the picture, a genuine signature is shown. On the left are two attempts at a freehand simulation made by three different people. Note (1) the inaccuracies, (2) the poor line quality, and (3) the similarities of the deviations from the genuine letter *D* within each pair.

the lower document. This can in turn be overwritten with ink to produce a realistic simulation of the original.

Another way is to place the original on the document where the copy is required and trace heavily along the line of writing so that impressions are made on the paper below. These impressions can in turn be inked in, the indented line being followed with a pen. The difficulty is to make the written line coincide exactly with the impressions, but the general shape of the copy can be reproduced adequately (Figure 3.2).

A different method is to place the document on which the copy is needed over the genuine article. The two are held up to a window so that the lower

Figure 3.2 A signature traced from the same genuine signature shown in Figure 3.1, photographed using oblique light. The indentations from which the signature has been traced can be clearly seen.

signature can be seen through the top paper. The lower signature can then be traced directly by writing on the upper document. A light box, a device used to examine transparencies or photographic negatives, can be used to provide a similar means of showing the lower signature through the top piece of paper.

Tracing paper can be used for the same purpose. It is placed over the genuine signature, which is then traced onto it. The other side of the tracing paper is then covered with graphite by means of a soft pencil lead being rubbed over the surface. By writing exactly over the first tracing, a graphite impression is left on the paper below. This can be overwritten to produce a simulated signature written in ink or with any other medium and the graphite can be removed with a pencil eraser.

There are other ways to reproduce a signature artificially, but these are less commonly used. Tracing a signature by any of these means produces similar results. The simulation will be a close match to the shape of the copied original. It will, in fact, normally be closer to the model copied than another genuine signature would be. It will show the same signs of slow, laborious production as a slowly written, freehand-drawn simulation. It may show lifts of the pen, poor line quality, and even pressure, in contrast to the smoother line with varying downward pressure caused by the speed of movement of the pen found in natural writing.

Unlike a freehand copy, it will be free or nearly free of the inaccuracies caused by imperfect observation or powers of reproduction. It will usually fall within the range of variation of the genuine signatures apart from dots or other small features that may not be noticed during the tracing. Unless it is a direct copy made by means of transmitted light, it will show evidence of the guide lines from which it was traced, and these can be detected by close examination in the correct light conditions. It is nearly impossible for the forger to follow the guide lines exactly, so the writing line will be found not to coincide with the guide line in several places. Guide lines will be detectable under oblique light or by electrostatic detection if they are indented impressions, or by low-power magnification and infrared examination if they are pencil or carbon. Despite the erasure of pencil or guide lines, traces of these may be discovered. Erasure may cause the simulation to smear and may damage the paper surface.

In most methods of tracing, the original signature will also show signs of having been overwritten; therefore, when guide lines are seen, it is important to establish that they are an indication that the signature has been falsified, rather than it being the model from which the simulation was made. By thinking about the method employed (e.g., are there traces of carbon?) and simply asking the question "Does the ink follow the guide line, or the guide line follow the ink?" this defense can usually be rapidly confirmed or dismissed. Occasionally, the housing of the pen can make indentations that follow the ink line and be mistaken for guide lines. However, as these are always a consistent distance from the ink line and often only when the pen is traveling in a specific direction, this can also be ascertained.

Introduction of Features of the Copier

When making an attempt to copy writing, the copier has to control his or her hand in order to reproduce the original as accurately as possible. However, the hand is accustomed to writing in its own natural style, so if concentration is reduced, a tendency to write in the usual way takes over. Therefore, simulated writings will often exhibit features that are not present in the writing being simulated, but rather are found in the normal habits of the writer. This is more often the case where a reasonable quantity of writing is copied and occurs less often if only a signature is simulated.

In some poorly made copies, there will be a mixture of the writing styles of both the person whose writing is being copied and the one doing the copying. The more obvious features of the writing of the former are noticed and reproduced, but much of the writing is close to that of the copier.

Where the natural writing of copiers intrudes into copies they are making, evidence is provided that might indicate the identity of the writer. Without such evidence, there is nothing to indicate who the writer is because each letter and feature of the writing has been based on the model copied. This situation is usual when signatures are simulated by careful drawing.

Copies of writings other than signatures are more likely to provide evidence of their writer. If certain letters are missing from the material being copied, they may be written in the natural writing of the copier because there is no model to copy. Rapidly written simulated signatures, which contain a relatively small amount of writing, sometimes provide evidence of their writer. When a number of such simulations are made by one person copying a particular signature, there is a tendency for them to show consistency between themselves as well as differences both from the genuine signature and from copies made by other people.

Traced signatures contain no evidence of their writer; the following of an indented impression or a written line has nothing to do with natural writing. The fact that naturally made signatures are never exactly the same means that the particular signature from which the copy was traced will be closer to it than any other natural signature, unless signatures of the genuine writer are remarkably consistent. Therefore, if the model signature is found and compared with the copy, it can be shown to be the source. Apart from close similarity in size and shape, it may contain ink from the pen that traced it or impressions of the simulation if this was made directly following the line of the underlying original. If multiple tracings are made from one genuine original, their closeness in proportion and shape will indicate that they have been made by this method. The finding of several such signatures may provide added proof that they are not genuine.

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Handwriting
The Purposes and Principles of Scientific Examination

4

Introduction

The previous two chapters considered the features of handwritings of different people and their natural, accidental, and artificial variation. In this chapter, the conclusions that can properly be drawn from these observations are discussed in outline. It is not possible in the space available to consider every factor that contributes to the final outcome of an examination of handwritings, but the basic principles are addressed. For convenience, in most of this chapter, reference is made to showing that two pieces of handwriting are, or are not, by the same person (common authorship). This should not be interpreted as indicating support for the idea that in comparison work, such as handwriting examinations, it is possible definitely to identify the source of the questioned material. The formal wording of conclusions for handwritings that show a high level of similarity is dealt with toward the end of the chapter.

Amateur Experts

Virtually everyone recognizes the writing of at least one person as well as his or her own. It is common practice to examine the writing on an envelope before opening it; workers in offices are familiar with each other's writing, as are members of families and other small social groups. This recognition, due to acquaintance with the writings, is not unlike the recognition of faces. At a quick glance, everyone can identify one of a large number of people by appearance, comparing what is seen with a gallery of faces in the memory. This ability, however, is not so great when handwriting is concerned. Too many writings will be too similar in appearance to allow an efficient separation. The memory bank of handwritings will not be as large as that of faces, and the power to discriminate between them is lower.

In another capacity, many people examine handwritings on a regular basis. Bank clerks, for example, may compare signatures on loan agreements with those on credit cards or driving licenses. Similarly, travelers' checks are paid on the strength of a similar cursory examination. The problem with identification or verification by a quick glance is that too much can be missed. The small but significant differences and the poor line quality of the simulation are not noticed; the subtle distinctions between the false and the genuine are not appreciated.

In other areas, small but noticeable features may be attributed great significance. In Shakespeare's *Twelfth Night*, Maria recognizes that she writes very much like her mistress Olivia. "On a forgotten matter we can hardly make distinction of our hands." She writes a letter, which Malvolio finds, and he falls into a trap. "By my life this is my lady's hand! These be her very *C*'s, her *U*'s and her *T*'s, and thus makes she her great *P*'s. It is, in contempt of question, her hand." But it was not Olivia's writing; it was Maria's.

The layperson will be impressed by overall appearance or by individual features that appear to match. The person will tend not to notice quite clear differences that are present. It is the experience of those who study handwriting that writings they find to be clearly and significantly different are regarded by the inexperienced as the same. Time and again the expert is presented with writings that are thought to be by one person and has to inform the client that they are not. The similarities that appear so convincing to the layperson are either common forms of letters typical of a style, sometimes called style characteristics, or less common features that can still occur by coincidence. With 26 letters of the alphabet, there are 26 chances of a coincidental match between one of them in two writings. When capitals and numerals are counted, the chances are increased. Again, styles widely taught or in fashion will often give the same appearance to writings.

In addition to confusion between different writers, the inexperienced observer may fail to realize that two totally different-looking writings can come from the same hand.

Scientific Method

The study, classification, and recording of natural laws of science have built up a background of knowledge that is consistent and repeatable. From this background, methods of determining the qualitative and quantitative makeup of materials have been devised. Analysis of such substances is based on performing a test, the results of which can be related to background knowledge about the material. Similar principles apply to the comparison of handwriting.

In reaching any conclusion from a comparison of handwritings, it is necessary to make accurate observations of those factors referred to in the previous two chapters and to weigh the evidence found in light of this background knowledge. This corpus of knowledge, built up by the study of many different handwritings in a scientific and analytical way, is essential for examiners and distinguishes their approach from that of the layperson.

To conclude that two writings were made by one person, it would be necessary to show that no other explanation is possible. The hypothesis that two writings are by one person must be tested by observation of the writings and by reference to the resemblances and variations found within and between those of members of the relevant population. It is not sufficient to note that the writings are similar, assume that everyone writes differently, and therefore conclude that they were written by one person. To do this is to ignore the possibilities of coincidence and of simulation. Only when the findings have been assessed against all the possible alternative hypotheses and these have been ruled out as practically impossible would the conclusion be justified. This is the fundamental principle for the reaching of conclusions for questioned handwriting; the same principle applies throughout forensic science.

Other Aspects of Forensic Science

In the comparison of fingerprints, blood, and other materials, the property that varies most within the population and least within an individual source is compared. The significance of the match is either calculated or estimated by the likelihood of finding a chance match elsewhere in the population.

When fingerprints are examined, this method applies. A chance match could be regarded as practically impossible once a certain number of features are found to agree, because of the randomness of the ridge characteristics. The comparison of marks made by shoes is, however, somewhat different. Mass-produced shoes in new condition will not provide different patterns, so coincidence cannot be ruled out. When damage, cuts, holes, embedded stones, and so on affect the marks, their random shape and position will not be reproduced in another shoe.

The consideration of a chance match in handwriting falls between those of fingerprints and shoe marks. Most of the features are not unique, but, like ridge characteristics, their combination is significant, and some, like a cut mark in a shoe, are very unusual.

When assessing the significance of a DNA profile found in a crime scene stain, a random match probability can be calculated based on the frequencies in the population of the different alleles being used. This sort of mathematical calculation is not possible in handwriting comparisons. First, it is not clear what is being counted, as each letter may have more than one feature of note. Second, it is very difficult to define a particular property or class equivalent to a clearly identifiable DNA allele. Third, while DNA alleles and fingerprint details are independent of each other and their frequencies of occurrence can be multiplied, many of the features found in handwritings are related and, therefore, such a mathematical treatment is not yet appropriate.[1]

Comparison of Handwriting

The initial examination of handwriting must be to determine if the writings are in fact similar, and, if this is so, consideration must then be given to the reasons for it. It has already been made clear that no two writings will be exactly the same, so it is necessary to decide whether the variations are typical of those of one writer or two. To do this, each letter of the alphabet is examined to determine its method of construction and proportions or shape. Although each will be different, its variations will fall into a limited range. The letters could be measured for height, width, angle, and other parameters, but the effort currently involved produces relatively little benefit. Observation of a number of examples will soon establish the average pattern of the letter. The shape of curves, angles, or ovals, openness of circles, length of lead-in strokes and connecting strokes, and the height of the point where the letter begins can all vary within a small range for one person and can be distinguished from the different range of another. Although some information can be obtained by comparing different letters with each other—the upper loop of the letters *h* and *k*, for instance—like is compared with like, *a* with *a*, *b* with *b*, and so on, and the resemblances or differences noted.

Consideration of Similarities

As the comparison of individual letters proceeds, it may become apparent that the range of each letter is found to be similar. When all the letters have been examined, when other factors such as size and slope, the distance between letters, their connecting strokes, the distance between words and lines, the margins and pen pressure, have been compared and also found to be similar, consideration is given to the significance of the findings. When writings are found to be similar, the only explanations are that they are by the same person, simulation is involved, or they resemble one another purely by chance.

In considering the significance of findings, they must be assessed against at least two alternative possibilities. In many cases, these can be that the writings are by the same person and that the writings are by different people and any resemblance is the result of chance or simulation. In determining which of these possibilities is the more likely, a number of questions need to be considered. Is it possible that a chance match has occurred? Could the similarities be due to the possibility that two people write these letters in an ordinary, frequently occurring way? Could the resemblances be due to the questioned writing being a simulation? Are the differences merely the variations expected in one person's writing? Are the similarities rare or common?

The Possibility of Chance Match

These questions cannot as yet be answered by quantitative data, and it is not certain that they ever will be. However, the wide range of variation found for each letter of the alphabet between different writers, the presence in many writings of unusual forms, and the number of characters present in writings being compared mean that the chances of finding a match between all the features in combination must be very remote or nonexistent.

Despite the fact that few mathematical data are available for the frequency of occurrence of different forms or the correlation between them, the basic statistical approach is applicable and logical. By relating the observations to their corpus of knowledge, document examiners can assess whether the resemblances between the writings are unlikely to be the result of a chance match. The basis of the corpus of knowledge built up by the questioned document examiner is derived from a study of many examples of handwriting of many different people and a knowledge of how they vary within each writer and between different writers. This study will enable the examiner to recognize whether features are unusual. Many document examiners, especially those working in forensic science laboratories, keep large collections of handwriting samples and can refer to these to assess the rarity of particular features.

The Possibility of Simulation

In many areas of forensic science, such as DNA, the significance of a high level of similarity is determined by the random match probability, although in some areas it may be difficult formally to calculate this. When writings are natural, this also applies in a handwriting comparison. However, another factor has to be considered with handwriting: it is possible to produce all the characteristics of a writer, however rare, by simulation.

Therefore, in addition to looking for similarity in method of construction, proportions, and general shapes of letters, the examiner must look for evidence of simulation. Inaccuracy, where letter forms will be close but consistently different, perhaps in method of construction, poor line quality, indentations, or remains of pencil or carbon lines that have been traced onto the paper, are all indications of copied rather than natural writing. If these are found, there is clearly reason to believe that the resemblances are due to simulation and not common authorship. If they are not found and the line quality is good, or at least similar to that of the known writing, that is, the writing of known origin, and if the resemblances are sufficiently close, then there is no evidence that the writing is other than normal.

This, in itself, does not totally exclude the possibility of simulation. Again, an assessment has to be made as to the likelihood that a person can copy the writing of another so closely that no evidence remains. In the case of a large quantity of well-formed, smoothly, and rapidly written text, this would be virtually impossible. At the other extreme, if a small amount such as a single poorly written word is the only questioned writing, the possibility that this is not genuine but rather is a copy made by another person cannot be excluded. In other comparisons, a situation between these two positions is found.

The same principles apply whether the writing in question is a quantity of writing or a signature; both alternatives, simulation or chance match, need to be ruled out as a practical possibility. While a signature contains only a small amount of writing, it will usually show other personal features such as choice of names or initials, underlining, and unusual letter forms that will provide adequate evidence against the possibility of chance match. The main consideration in the examination of signatures is the possibility of simulation.

Subjectivity

In any assessment of evidence derived from examination of documents that depends not on mathematical calculation but on the evaluation of the significance of all of the findings taken in combination, there must be a subjective element. As well as a possible variation in observation of the documents in question and in awareness of the background knowledge of the subject, there may be elements within the personality of the expert that play a part—a tendency to caution or to the opposite, perhaps. In addition, there will be variations in the competence of the different examiners.

It is important for any person practicing the science of document examination to be aware of this. It is part of the training of students in any scientific discipline to be aware of the limitations of the methods they are using. They must know how exact their methods are and report their results within those limits. Inexactness is normal in many disciplines; an "exact science" hardly exists, and a qualified scientist is well able to allow for it. The conclusion of the examiner must be made allowing for any lack of precision inherent in the methods used. The subjectivity of the reasoning process must be recognized, and in the circumstances leading to a criminal trial, the benefit of any doubt must be given to the defendant. The issue of cognitive bias in forensic science has become an increasingly important one. While it cannot be eliminated, it can be reduced by, as far as possible, preventing the expert receiving information about the case that is not relevant to their examination, such as, for example, the fact that the alleged writer's fingerprints have been found on the questioned document.[2]

It is a long way from the careful, well-based consideration of the evidence and its reasoned evaluation in reaching a conclusion to the guesswork that is sometimes implied by the word "subjectivity." The idea that a degree of inexactness of method is equated with a random or ill-considered personal choice is erroneous. The use of the word "opinion" in legal circles to describe the conclusion of an expert may give rise to this because the same word is used in everyday speech to indicate a degree of uncertainty. In contrast, the conclusions of a properly trained and competent document examiner are found to be consistent, accurate, and sound. The subjective element, recognized and allowed for, is reduced to an absolute minimum, and there is, with few exceptions, close agreement between the findings and conclusions of different competent practitioners.

Common Authorship

When two handwritings are compared, if both coincidence and simulation can be effectively ruled out, the conclusion of the expert could be that both the known and questioned writings are by one person. The examiner has taken into account all the variations and similarities in the writings and their significance. These have been related to the background knowledge on the subject amassed by both the examiner and his or her colleagues, and all other possibilities have been considered. In the expert's view, only one reasonable conclusion remains, and that is one of common authorship. It is as if the expert has unwillingly come to this conclusion, having diligently sought and failed to find evidence for some other explanation. The only other inferences are that by some remarkable coincidence, well outside the expert's experience, someone else writes like this, or someone with an extraordinary skill can produce the perfect simulation, leaving no evidence. The expert considers the likelihood of these possibilities being correct so remote as to be negligible, and no practical chance that they have occurred exists. Whether such a conclusion should be given in evidence to a court is currently a matter of some debate and is discussed in more detail later.

Qualified Conclusions

In some circumstances, questioned handwritings are small in quantity. The same principles apply to these cases as to those where more writing is available. Each letter of the alphabet is compared with the same letter in the known writing, and if all are found to be similar and within the expected range of variation, and there is no evidence of simulation, there is no reason to believe another writer is involved. However, the possibility cannot be excluded because the amount of material available for comparison is insufficient to exclude a chance match. If the quantity of similar writing, though less than that sufficient for a conclusion that it was made by one person, is nearly so, the evidence is still strong. The chance of coincidental match may not quite be negligible but is very unlikely, because there is a reasonable amount of writing or a smaller amount with some uncommon features. It then becomes highly unlikely that another writer could be found who, by chance, writes in the same way. The evidence is, therefore, very strong that the two writings were written by one person. This conclusion, not as strong as saying that the same person wrote them, but stronger than mere consistency, is of considerable value.

In other cases, there is a smaller amount of writing without sufficient unusual features, so a coincidental match can neither be ruled out nor regarded as very unlikely. There will be many people whose writings will not match the writing, but a real chance that some will. This is especially so when the writing is poorly formed and likely to be somewhat variable around a common style not far removed from that of a copybook. In these cases, the evidence is more likely if the writings are by the same person than by different people. The correct conclusion would be that the evidence is still positive but rather weak. Exactly how this is expressed varies considerably between different document examiners. Such a conclusion may be of little use to a court. It certainly would not be sufficient, if produced by the prosecution without any other evidence, to secure a conviction in a criminal trial, although it may still be of assistance in a civil case where a balance of probabilities proof is required. However, if other evidence is present, the conclusion could be corroborative to the prosecution case. Similarly, it could assist the defense if it suggested that a prosecution witness was not telling the truth.

Limited Populations

The evidence produced from a handwriting comparison depends, as fingerprint evidence does, on the consideration and rejection of a large population—separating one person from an extremely large number. However, in some handwriting cases, the circumstances might indicate that only one of a small number of people could be involved, and samples of writing of all of them may be available. Clearly, if one is found to be similar and the rest are different, significant evidence is obtained. Simulation must not be ruled out because a particular individual could have been "framed," but, in situations like this, conclusions of great importance can be obtained from a small amount of writing.

Consideration of Differences

The comparison of any two pieces of handwriting will show that there are differences between them; even when two pieces of writing by one person are compared, no two words will be precisely the same.

In some cases, there may be similarities, sometimes quite striking ones, but there may also be differences that consistently occur. Each time a particular letter of the alphabet is found in the questioned writing, it is very different from those of the known writings. The range of all the examples of that letter found in the questioned writing is outside or separate from the range of the letter found in the known writing. The same may be true for other letters. Some letters may appear at first sight to be very similar, but when all those in the known writings are examined together, they are found to be consistently different from those in the questioned writing in some small feature—the position of the cross bar of a *t*, for instance, or the height at which the down-stroke of a block capital *A* begins.

The presence of these differences is worth consideration. Why should one person write a number of letters in one way on one occasion and in a totally or slightly different way on another? If the known writings have been collected from examples written over a period of time including that of the questioned document and are found to be consistent in themselves, why should the questioned writings differ in these respects?

Consistent Differences

When variations are found in a letter or figure, they can be considered as falling into a range represented by an enclosed area such as a circle. The variations of the same letter written by another person can be regarded as being enclosed in a different area or circle. These areas may be large or small, depending on the variability of the writer or the particular piece of writing. If the two writers make the letter in a similar way, the circles will completely or partly overlap. If they are consistently different, the circles will remain apart. Using this analogy, it is easy to visualize that although one person could use a wide range of variation, occupying a large circle, it is difficult to see why he or she would use two separate, discrete ranges represented by two circles that do not overlap. Occasionally, this will happen with one letter; it is not uncommon to find a letter *b* written both with an anticlockwise base opened upward and with a closed circle in the same piece of writing. Sometimes the right-hand vertical stroke of a block capital letter *N* will be made in either an upward or downward direction in the same writing. Generally, however, there is no reason to expect consistently different forms from one writer.

The consistency of the differences between two writings is, then, a most important factor. It is usually unwise to attribute two writings with such a discrepancy to one person. It is, however, rare to find only one such difference if adequate writings are available for comparison. Normally, there will be several or many consistent differences between writings of any two people, even when they appear to be similar in overall appearance. The presence of these differences, despite some similarities in style or between certain other letters, is an indication of a different writer, and there is therefore no reason to believe that the questioned writings were written by the writer of the known writings.

Other Reasons for Differences

It is not possible in most cases to say with certainty that two different writings must have been written by different persons because there are various ways in which a person can write so that one writing sample is different from another. Some people, a very small proportion of the population, can write quite naturally in totally different modes. Perhaps one is an italic style, and another one more conventional; perhaps both are in the same basic style.

Disguise is another possible cause of differences in the writing of one person. Although it is difficult for most people to introduce into their natural writing differences so consistent that they are present in each example of the chosen letter, this is not entirely impossible. If the amount of writing is small, the task becomes easier.

A not uncommon method of disguise, writing with the "wrong" hand, produces a badly formed and poorly controlled writing. This could be thought to be the normal writing of the subject, but can be excluded by adequate samples of "course-of-business writings" (see Chapter 5).

Again, by copying the writing of another person by a variety of means such as simple drawing or tracing, writers will produce a result totally different from their normal product. These factors make it unwise to conclude that two different writings must have been made by different people. Normally, this will be the case, but the degree of certainty is reduced by these possibilities; without any knowledge of the ability of the subject to write in different styles or to disguise effectively, the likelihood of this cannot be assessed.

Nevertheless, there are many cases where the known writing, that is, writing known to be by a particular person, is found to be of a generally poor quality, showing clear evidence of lack of skill, and it is sufficient in quantity for it to be reasonable to take it as representing the normal writing of the person. In these cases, if the questioned writing is not only different but of higher quality, it can safely be assumed that the writer of the poor-quality known writing would not be able to achieve the standard of the questioned writing and so could not have written it. There are other occasions where the construction of letters is consistently wrong, so that the evidence suggests it is most unlikely that one person has written two writings. Caution here is also advisable. Ambidextrous writers, a small but not insignificant proportion of the population, might find one method of construction less convenient with one hand than with the other and so change methods with a change of hand.

Therefore, in most cases where writings differ from those with which they are being compared, it is usually best not to conclude that they must be by different people, but rather that there is evidence to support the view that this is the case.

Similarities with Differences

So far, discussion of possible results for handwriting comparisons has assumed that there is either no significant difference between the known and questioned writings or that such differences are sufficient to provide good evidence supporting the view that they are by different people. In practice, this is often the position, and the assessment of the value of evidence is dependent on the amount of writing available for comparison. Sometimes, however, the situation is complicated by differences that are not so clear-cut as to be significant in a negative direction. There are many reasons why these might occur (see Chapter 3). Disguise, simulation, ill health, and difficult writing conditions all contribute to differences from what might be regarded as normal writing.

Disguise

Features generally found in disguised writing are also described in Chapter 3. There is a tendency for a distortion of overall appearance with the retention of the detail of method of construction and proportion. Also, the disguiser finds it difficult to maintain consistency for a lengthy period of writing. Similarly, the tired, ill, or intoxicated writer, as well as a person writing in difficult circumstances, will also keep those same features. The subconscious movements of the arm, hand, or fingers produce the same method of construction of each letter and the propensity to write with the same proportions. Such detail will be little affected by deliberately altered appearance or by difficulties of less than ideal conditions. In contrast, an adequate sample of writings of another person will be certain to include some letters made in a consistently different way. Provided that enough material is available for a comparison, the differences found can be established as consistent in form and detail, or, alternatively, variable only in the more general features but similar in the finer points of construction and proportion.

From the determination of which of the two situations is present in the questioned writings the appropriate conclusion is derived. It may be possible, despite the differences, for the expert to conclude that there is very strong evidence to support the view that both writings were made by one person. In many cases, the degree of doubt present means that a weaker conclusion should be employed.

Where differences occur that are typical of those found in disguised writing, this can be reported. It may be of interest to a court that some form of deception has been attempted. However, only those features that can be attributed with certainty to attempted disguise should be reported. It would be wrong to accuse the writer of disguising his or her writings if differences from normal were due to other reasons, such as ill health or the influence of alcohol.

However, the most serious error is to attribute consistent differences to disguise and therefore pay insufficient attention to their cause.

Simulation

A further cause for apparent similarities occurring alongside differences is that one of the pieces of writing being compared is a simulation. The methods used to simulate writing, mostly signatures, of other people were discussed in Chapter 3. Whether the method chosen is a rapidly drawn copy, a slowly made freehand simulation, or a tracing, evidence (poor line quality, pen lifts and retouching, inaccuracy, use of guide lines) will normally be found. In many cases, the observation of such features provides clear evidence that simulation has occurred.

This, however, is a simplification of the position. The natural variations found in the writings of one person can be mistaken for evidence of simulation. If inadequate samples of signatures known to have been written by the person whose signature is in question are available for comparison, the whole range of variation will not be apparent to the examiner. This means that what appear to be significant differences due to inaccuracies in copying may be variations not represented in the known writings. It is difficult to quantify the minimum number of signatures needed to establish the range of variation, but between 10 and 20 made over a period, preferably including the time of the signature in question, are usually adequate. Fewer could be sufficient if there is clear evidence of simulation in the suspect writing or consistency of difference between a number of simulations and the genuine signatures.

When significant differences typical of those found when signatures or other writings are copied are discovered in a questioned signature and those differences are not present in any of an adequate number of those known to be genuine, it can safely be concluded that the signature is not the normal signature of the subject. If the questioned signature also shows a clear overall similarity to the genuine signatures, too close to have arisen by chance match, it can be reported as a simulation.

It is usually unwise to report that the questioned signature "was not made by the person whose writing has been simulated." The reason for this is complicated. Although it is not uncommon for a person to write a signature with the intention of later denying it, the obvious method of doing this is to disguise their writing. This will produce different characteristics in the signature as the signatory is now trying to create differences between genuine and denied signatures while the more usual method of simulation by another person seeks to match the writing being copied as closely as possible. The person simulating his own writing will normally make sure that they can point out a difference when they later claim not to have made the writing. However, this is not always the case. There is nothing to stop the genuine signatory adopting the usual methods of simulating writing, including tracing, when writing a signature later to be denied. It is for the document examiner to point out the possibility of these practices, but as with writings that are both natural and different, they are not able to state with certainty that the simulated writing was not made by the person to whom it is attributed. There are exceptions to this—a clearly superior standard of writing in a simulation may show that the questioned signature could not have been made by the person who should have written it. What may or may not have happened could depend on other evidence within the knowledge of the court.

If a number of questioned signatures are available for comparison and they show consistency in their differences from the genuine signatures, this will increase the evidence that they are simulations. In a single signature, a departure from the genuine signatures available for comparison may be accidental, but in a number of signatures, especially if made on different occasions, any consistent differences are far more likely to be caused by a habitual error of the simulator. They also provide evidence that the simulations were made by one person.

Not every simulation has clear evidence of poor line quality, retouching, and other "classic" features that demonstrate its deception. Others, especially those made when copying simple short signatures, may have a line quality not very different from the signature and be formed without pen lifts, retouchings, or tracing. In these cases, it may not be possible to say with a high degree of certainty that the questioned signature is a simulation, but, depending on the degree of inaccuracy that may be present, it may be possible to indicate that it is probably so.

Simulations or Ill Health

In some circumstances where there is writing of inferior quality, a poor line quality could be mistaken for evidence of simulation, especially if some accidental differences are present. In cases where the signature of a person is affected by infirmity, the same slowness and shakiness associated with copying are found. The most apparent difference between the two causes is that while the tremor of illness is often of even and uniform amplitude, the poor line quality of a slowly moving pen attempting to reproduce the writing of another person is irregular and jerky. In addition, the resemblance in method of letter construction and proportions both within and between the letters is likely to be close to those in the known signatures if the questioned signature is genuine. It is more likely to be poor in a copy. However, a good copy may be difficult to detect in these circumstances, and a strong conclusion on the genuineness of the signature may not be possible. In this event, a more qualified answer may be given to the client or court.

In cases where signatures are compared, it is important to notice changes that may occur with passing time. Even without ill health playing a part, a person may modify his or her signature gradually over a period of years or even months. After the onset of illness, the signature may deteriorate rapidly. If a questioned signature is purported to have been written on a particular date, it is important to have contemporaneous material to compare; otherwise, differences may be attributed to forgery when they are in fact caused by change of habit or failure of health.

Of course, the copier might choose as a model a signature made at about the same time as that of the poorly formed signature of the invalid. This is particularly likely if a will is dated toward the end of the life of the testator. Here, the simulation of a signature might be easier. Instead of the difficult task of trying to reproduce a smooth line and an evenly graduating curve, the forger has to copy a poorly written signature with a shaky appearance. The task is still not easy, however. The proportions of the poorly written genuine signature are more likely to be consistent with each other than with those of a copy. The frequency of oscillation of the line of writing is likely to be even, while the line quality of the copy will possibly break into a smoother phase if concentration lapses. Trailing lines between strokes are also difficult to reproduce in a simulation.

Traced Writings

A common form of simulation is tracing. The traced signature or, occasionally, other writings may be associated with guide lines such as indented impressions or graphite or impressions from carbon paper (see Figure 3.2). Examination under oblique lighting or by electrostatic methods will detect the impressions, and microscopic examination or the use of infrared radiation (see Chapters 7 and 8) will discover any graphite that may be present. Attempts to remove graphite guide lines by using an eraser may leave damage to the surface of the paper or smear the ink. The use of lycopodium powder may show evidence of erasure (see Chapter 9). Examination for guide lines is therefore made, and their discovery is clear evidence of tracing.

There are, however, other considerations to be made. Some genuine signatures are written over light pencil writings made to indicate where the signatures are to be placed. To be sure that a signature has been traced, therefore, it is essential that the closeness of match between the signature and what appear to be guide lines is sufficient to rule out coincidence. There will always be places in a traced signature where the tracing does not coincide with the guide lines, but for the most part, there is normally a close match. Care must also be taken to avoid erroneous conclusions when what appear to be written guide lines are discovered. Some pens, when held at a certain angle, will make indentations parallel to the line of writing, very close to it and usually only on one side of the line. These are too closely associated with the written line to be regarded as indentations made before the line and subsequently followed, but there is some danger of a mistaken interpretation. Sometimes a defective pen will write with an uneven intensity of ink, a darker striation appearing within the line. This can be mistaken for a tracing line, but, again, it is too consistent in position for it to be a guide line.

It is sometimes the practice for genuine signatures to be made successively on a series of documents in the same location on each page. Indented impressions of one will then be found close to the next signature to be written. These could be wrongly thought to be guide lines. It would, however, be a remarkable coincidence if they matched at all closely; normally, they would be too far away from the written signature to be mistaken for guide lines. Some people write their signatures very consistently, but to find another signature whose impressions match both very closely in shape and in position, diverging only slightly from the written questioned signature, would be virtually impossible. In addition to the presence of guide lines, the line quality of the signature itself will be poor, similar to that of a slowly written freehand signature.

If a signature has been traced directly from another, no guide lines will be found around it. It may therefore be indistinguishable from a slowly written freehand signature. If, however, the signature from which it is copied is found, its origins will be established by the closeness of match and by the discovery of indented impressions associated with the original. Even without the original master signature, tracing can be established if two or more traced signatures are found that match each other too closely to be genuine.

Identification of the Writer of Simulations

Simulated writings can be compared with those of the person suspected of writing them, but only where the simulation has been unsuccessful and has not been accurately copied is there any evidence of the natural writing of the copier. In a short piece of simulated writing such as a signature, there is likely to be very little if any evidence to indicate who wrote it, especially if it has been made slowly. With longer passages of writing, there is a greater chance of finding characteristics of the writer. If the writing being copied is deficient in some letters of the alphabet, the copier will probably use his own method of writing to complete the simulation. In such cases, there is a considerable difference between some letters, which match those of the known writings, and those that are totally different because they are based on the writings being copied.

Traced writings are unlikely to show any evidence of the writing of the tracer. Nevertheless, the discovery of the signature that has been traced will be of considerable importance; it may indicate with certainty who made the tracing from it.

Freehand simulations of a signature made by one person will generally be found to be consistent, differing both from the copied signature and simulations of the same genuine signature made by other people. This is not only because the copier may leave evidence of his or her own writing, but also because people appear to be consistent in the way they copy writings and in the errors they make (see Figure 3.1).

When a number of simulations are made by several people using the same model signature, the simulations can be placed into clearly defined groups, each group containing copies made by one writer. In these cases, the variations are not necessarily related to the writing characteristics of the forgers, but rather to their methods and skill in simulation.

Inconclusive Examinations

In many cases, where only a small amount of writing is presented to the examiner, little of value can be deduced, or the evidence is totally inconclusive. There is no reason why the handwriting expert should not state that the evidence is insufficient for any useful conclusion. If they are unable to indicate in which direction the truth lies, it is right that they do not give vent to their suspicions or their feeling about the matter. When there is no hard evidence either way, no conclusion should be given.

Complexities of Handwriting Comparisons

In many cases, a comparison between one piece of questioned handwriting and one sample of known writing is all that is required. In other cases, there may be a number of documents, each with writing to be compared. A further difficulty could be that each document has more than one entry on it and different writers have made them. There may be more than one suspect—in some cases, a large number. These cases require more than a simple comparison; they require management as well.

In the experience of every document examiner, there are cases where the supplied information is inaccurate. They may be told, usually in good faith, that a particular document bears the writing of a certain person, but find later that this is not so. The investigator may not have taken sufficient care to ensure that because writing is found in a certain place, it is by a particular person. It is therefore a sensible precaution for the examiner to compare all their known writings before comparing them with the questioned material. This need not take a long time; it will usually be quickly apparent if the various known writings are not consistent.

Inconsistent Known Writings

It is not always easy to be sure that two apparently different writings described as known writings of one person are not by different people. First, as has been referred to earlier, some people can write naturally in more than one style. Second, if an effective disguise has been employed in the samples given on request, these may be very different from the course-of-business writings.

In cases where there is doubt that the known writings are by one person, the examiner should return to the investigator and ask how sure he or she is of the authorship of the writings. If the complication is not cleared up, the questioned writings should be compared separately with each batch of known writings. If the known writings are by different people, only those that can be attributed to the subject with certainty will be of value in the investigation.

In any one document, it is possible that the writings are by a number of different people. An address book or a diary may include entries written by various writers, and this may cause problems in establishing known writings. The same considerations can apply to questioned writings. If there are original entries to which are added small amounts of writing, the additions may not be so different that it is apparent that they are by another writer. They can then confuse the comparison of the whole. In some cases, the additions will be made with a different ink and can therefore be recognized as not part of the original. It is a wise precaution to use the method involving absorption and luminescence of infrared radiation, described elsewhere in this book, to investigate this possibility.

Complex Cases

In complex cases involving many documents, there is much to be gained by comparing the questioned writings before comparing the whole with the known writings. Although there is a danger that some of them may not be used in later proceedings and therefore may not be available then, this exercise is worthwhile. For example, in the investigation of a large check fraud involving a number of checkbooks, it may be found that one writer has varied his or her writing to match the signatures that he or she has simulated. Despite these differences, the detail is likely to be similar, and there will be much in common between the writings of each book. They will share the same words, figures, and layout. Checks that in themselves show little resemblance to the known writing may be positively connected through others when it is clear that all are by one writer.

Signatures are often treated separately from other writings on a questioned document when being compared with known writings. Often, an attempt is made to simulate the target signature while the rest of the writing is written naturally. Evidence of the writer is then found only in the main body of the writing. It is normally not possible in these cases to find appreciable evidence in the simulated signature for any indication to be given as to whether the writer of the rest of the writing was responsible for the simulation or whether another person made it. In other cases, where no simulation has taken place and the signature and the other writings are consistent in themselves, they can be regarded as one piece of writing.

Sometimes the perpetrator of a large fraud will sign in a variety of different names and will leave his or her writing in small quantities on many documents. Provided that there is clear evidence of a connection between all these fragments of writing, they can be accumulated and compared as a whole with the known writing. If they, both in parts and together, are found to be similar to the known writing, then the evidence that the known writer wrote them may be very strong despite the fact that this would not have been the case with only one of the fragments. Although coincidence cannot be ruled out with any one fragment of writing, it can be if all are taken together. If an objection is made to this assumption, then the only other possibility is that a series of different people, who all write in a manner very similar to the known writings, are responsible. This, too, is not a viable explanation, and only one conclusion—that of common authorship—remains, provided that simulation has been ruled out.

Multiple Suspects

There are occasions when it is necessary to compare a particular piece of writing with known writings of many people, all of whom might be possible suspects. This has been done in the United Kingdom in several murder investigations when the writer was thought to come from a particular location. Thousands of samples were gathered and compared with the questioned writing. To do this, certain features of the writing were chosen, and only those were compared. If they were not similar, the sample was discarded. It would have been impossible and unnecessary for more to be done. If the features were similar, the writings were compared more fully. Although the culprits were not detected by this means, they would have been had their writings been included in the samples originally examined. In two of the cases, the writers were found by other means, and their writings were identified with the questioned documents.[3,4] These exercises illustrate the value of a scientific approach to handwriting examination, as questioned writings have been compared with writings of hundreds or thousands of people of a similar background and none have been wrongly identified or suspected.

Reproduced Writing

Difficulties can arise in handwriting comparisons for reasons other than complexity. So far, only writing written directly onto paper has been considered, but it is often reproduced by some photographic method such as photocopying or scanning. Although some of the detail will not be apparent, in many examples of good-quality images, there will be adequate material for a useful comparison to be made. What will not be reproduced are indented impressions that have been used as guide lines in a simulated signature. Similarly, erased lines will not be detectable. However, provided that these possibilities are allowed for, there is no reason an appropriate conclusion should not be reached. If sufficient detail is visible in the image, much can be adduced. It is possible to identify imaged writing as having been made by the known writer.

Care must be taken to distinguish between the writing and the document on which it appears to be written. The writing may be genuine, but the document may not. The reproduction could be a composite of two or more documents, and so the writing appears in a context different from that in which it was intended. This is especially true when a genuine signature is pasted onto a fraudulent letter. This process is dealt with in Chapter 8.

Similar situations of "secondhand" writings occur in prints from microfilm, carbon-copied writing, and indented impressions detected by oblique lighting or by electrostatic detection. In all of these processes, it is possible in some cases to find enough detail for evidence of the writer to be found, but in other cases, there will be insufficient material. In particular, with carbon writings of poor quality, it may not be possible to rule out the possibility that the writing has been traced from a previously written model. When sufficient precautions are taken to allow for the possibilities of error, useful evidence can be obtained. It is unwise to reject photocopies, carbon copies, photographs, or any other reproduction without attempting to discover what evidence they contain.

Unfamiliar Scripts

Document examiners normally work on writings in their own language and have little difficulty in recognizing each letter; they can refer to their experience of variation found within and between writings of styles familiar to them. The examination of handwriting in languages and scripts that are not familiar to the document examiner can present particular problems. Working in an unfamiliar language that uses the script with which the examiner is already familiar presents fewer problems than working in an unfamiliar language and script.

The principal issues when working with an unfamiliar language that uses the same script as the examiner's native script are ensuring that characters are correctly identified and determining the significance of observations. A knowledge of the usual copybook styles taught in the country in question can be of great assistance in ensuring that characters are correctly identified. Many characters will be identified correctly anyway without problems, but the assistance given in the examiner's own language by the context is now lost. Provided examiners remember that the comparison stage of the examination is only that and they restrict what they are doing to describing accurately what can be observed, this part of the examination should be largely unaffected by working in an unfamiliar language.

The difficulties of working in an unfamiliar language are compounded when the script is also unfamiliar, as is the case, for example, with a person familiar with Roman script examining writing in Arabic script. The question is sometimes raised: "How can a handwriting examination be carried out if you don't speak the language?" This question really resolves into "How can you carry out a handwriting comparison if you can't read the script?" as it is rarely raised when only the language is unfamiliar but the script is familiar. Involving an official translator can solve the problem of identifying the individual characters, but this process is time consuming and costly. It also does not inspire confidence that the examiner has sufficient understanding of the script for any conclusions he or she may eventually reach to be reliable.

A basic knowledge not only of the script but also of the language is really a requirement for the examination of writings in unfamiliar script. It is not necessary for the knowledge of the written language to be such that a text can be formally translated, but it should be sufficient that with the original text and a translation into the examiner's own language, the examiner can appreciate how that translation was produced. With such knowledge, the identification and description of characters can be as accurate as in the examiner's own language.

The issues associated with the evaluation of the observations are similar whether the comparison involves only an unfamiliar language or whether it also involves an unfamiliar script. The main issue is the limited background knowledge concerning how common or rare particular forms of a character are. It is important to be very cautious in whatever conclusions are reached, but it is possible to give assistance to the investigator and the court by carefully applying some basic principles. These are that: if there are clear and consistent structural differences between two pieces of writing, then a conclusion suggesting that there is evidence they were written by the same person should not be reached; a character with a structure that is awkward to write is likely to be uncommon; the presence of a character or characters with the same multiple structural forms in writings by different people is also likely to be uncommon; and writings by different people would not be expected to have all the same structural forms with the same ranges of variation.

While the application of these principles on their own should not result in a strong conclusion, they do provide a basis that will allow the examiner to give some degree of guidance on whether two pieces of writing in an unfamiliar language or script are likely to be by the same person.

The methods of simulation are the same in any language or script. The same evidence of poor line quality, inaccuracy, and other features described earlier are found because the same reasons for them apply. In addition, tracing may be used, and guide lines and other evidence for this can be found. Again, even with stylized signatures where every letter of the name is not written, the assistance of a translator to identify letters that are present is helpful.

Statements

Having reached a conclusion, the forensic document examiner has to report it. This can be done verbally or informally in a report or a letter, but for possible litigation, a statement or affidavit is prepared. Statements are normally made in the first person. Unlike scientific papers and reports, where the passive voice is used, the court requires the witness to take personal responsibility for what is said. The conclusion should begin with the personal pronoun. Statements and affidavits, therefore, should be worded in the same way, and reports not intended for submission directly to the court are best worded similarly.

It is necessary in testimony, and therefore in statements, to indicate that the witness has some grounds for being allowed to give expert evidence. Qualifications should therefore be stated. Academic attainments and length of experience in the examination of handwriting are usually of interest to the court. Some examiners add that they have published papers, attended conferences, and presented lectures. None of these guarantee that the expert is competent; even length of experience is not a certain indication of this. Those employed in forensic science laboratories usually include fewer qualifications in the statement than those practicing independently; the reputation of the laboratory, especially if it is formally accredited, may be accepted as a guide to the validity of the witness.

After the statement of the expert's qualifications, the substantial part of the statement begins. This may be long or short depending on the need of the recipient. One method of writing a statement is to describe in considerable detail all the features found and their significance, followed by the conclusion. In another, the findings are summarized briefly and the conclusion is given. If illustrative charts, which are dealt with more fully in Chapter 11, are used, their content may be described in detail. Alternatively, they may be briefly referred to, and the description of the features found reserved for the court, should it be necessary.

Expressing Conclusions

The most important part of any report or statement of findings of a handwriting examination is the conclusion. It is imperative that this be clearly expressed and not written in a way that can be misunderstood. The conclusion of an expert witness is referred to in court as an "opinion." The word has a meaning special to the legal process; experts giving evidence deliver an opinion. Its meaning is different from that normally used outside the confines of a court and its surroundings. To have an opinion about anything—a play, a musical performance, the views and actions of a politician, or whether it will rain shortly—is a prerogative of anyone. The opinion of one person will differ from that of another; everyone feels that he or she is entitled to his or her own opinion, whatever anyone else may think. The use of the word "opinion" in this context should not be confused with that of the expert witness in court, either by the witness or by the receiver of the report.

The technical term "opinion" is synonymous with "conclusion." Whether that conclusion is strong or weak, it is the expert opinion of the witness. Unlike the wider use, it does not convey the degree of doubt implied in the phrase "it is only a matter of opinion." This is not always realized by the writer of the report or lawyers reading it. Although the phrase "in my opinion" followed by the result of the examination is a perfectly adequate method of expression, the fact that misunderstanding may take place as to its meaning is good reason to avoid it. Otherwise, it might be confused with the opinions of those who regularly predict the winners of races in the newspapers. It is best to use the expression "I concluded that…" or "It is my conclusion that…". This is less likely to be misunderstood.

Qualified Conclusions

There is some difference of view among those who practice forensic document examination as to how handwriting conclusions should be reported. Many people who compare handwritings would take the view that they should report that, where the evidence warrants it, they have concluded that the two writings were written by one person. They are also agreed that comparisons of different writings should be reported as such. Others would argue that conclusions expressing "certainty" are not scientifically justified and all conclusions must be expressed in terms of the degree of support they give to a particular hypothesis for the origin of the questioned writing. However, provided it is made clear that a conclusion of "certainty" is simply an expression of the expert's assessment of the evidence, it should not be considered objectionable. It is important that such a conclusion not be claimed to be more than that; especially, it must not be claimed to be an objective fact, and phrases such as "conclusive evidence has been found" should be avoided. Also, such a conclusion can be used only where the court permits it.

There is also disagreement in those areas where the evidence is insufficient for the expert to say that he or she considers the only reasonable conclusion to be one of common authorship and the writings are not so clearly different as to indicate that there is no connection between them. There is a school of thought that holds the view that all these comparisons should be reported as inconclusive. In other words, if the evidence is sufficient for a conclusion of common authorship or an exclusion, this should be reported; if not, no conclusion should be offered.

The positive, negative, and inconclusive method of comparison is attractive in its simplicity but is difficult to justify scientifically. No problems exist in explaining what is meant by any uncertainty in the conclusion, but it ignores the fact that all conclusions have an element of uncertainty. It does allow the amount of work to be reduced, as the examination can be stopped as soon as it is realized that the evidence will not reach that required for a certain conclusion. The client receiving the report may not be interested in half measures. With a conclusion of common authorship, he or she can take some action; with anything less, he or she can do nothing.

Most handwriting experts would now express their conclusions in a manner commonly used in other areas of forensic science by referring to the degree of support given to a particular hypothesis of origin. The findings of the comparison are considered against the expectations that particular hypotheses about the origin of the questioned writing produce. So, for example, the hypothesis that writings are by different people leads to the expectation that consistent differences will be found. If this is the case, then the findings can be said to provide support for this hypothesis. The final conclusion is reached by considering how well the findings support each of the possible hypotheses for the origin of the questioned writing and determining the balance of that support. This has much in common with the way evidence is assessed using Bayes theorem, but it is important that it be made clear that the final conclusion is not a statistically based likelihood ratio but an assessment by the examiner of where the balance of the evidence lies.

Where the evidence provides only some support for the view that handwriting is by a defendant, and there is other evidence such as a visual identification that requires corroboration, the handwriting evidence will be of value. In virtually every circumstance and every court hearing, there will be more than one piece of evidence. That of the handwriting expert, whatever strength it is, will provide a part of the total testimony in the case. It could be a substantial part or merely a small piece of corroboration, depending on the strength of the conclusion and the weight of the other evidence. Similarly, a qualified conclusion that the questioned writing was written not by the defendant but by, say, a prosecution witness who has denied it may be of great assistance to the defense.

Scales of Conclusions

To express any conclusion, appropriate words need to be chosen to convey the meaning intended by the examiner to the reader of the statement or to the court. The range of conclusions could, if quantitative measurements were possible, be numbered between 1 and 100, or with greater discrimination between 1 and 1000. This, however, is not possible. Unlike DNA casework, no such numerical precision is available in the assessment of the probability of coincidental match in handwriting, nor is it available in the calculation of the likelihood of simulation. As with most other evidence types, the interpretation of conclusions in handwriting comparison uses what is commonly known as the "likelihood ratio" approach. There has been much discussion about how this might be applied and how a numerical likelihood ratio could be calculated for handwriting comparisons.[5,6] These may provide some assistance to the document examiner in understanding the decision-making process but given the complexity of the subject it would be misleading to place too much reliance on calculated numbers. Instead, the document examiner will use the words they consider most appropriate to the conclusion they have reached.

There is not much to be gained from using a large number of expressions giving finely distinguished differences between conclusions. It is better to keep to relatively few categories so that each will represent a range of degree of certainty rather than a point. There are two reasons for this: (1) it is not possible to assess a point on a scale or within a narrow range with sufficient accuracy, and (2) if two different conclusions are expressed in terms that make only fine distinctions between them, the differences will make little impact on the court. It is better to confine the expression of conclusions to a short scale where different words represent real differences from each other.

The various terms used to express the degrees of support for a hypothesis of the origin of a piece of handwriting can therefore be summarized into a scale, each point representing a different level of support for the hypothesis of the source of the material. Although there is some variation between document examiners in the terms they use, many use a short scale of perhaps four or five points, expressing different levels of support for the hypothesis of common authorship and an area where no conclusion of any value can be given. The scale is normally symmetrical about the inconclusive point, and the negative side describes support for the hypothesis that the writings are by different people. Some scales will also include a point for a conclusion of common authorship and one indicating that the writings are by different people. If genuineness or simulation is the issue, different wording may be used and the results can be expressed in terms of support for the hypotheses of genuineness or simulation.

Clarity of Expression

When expressing any conclusion, it will be apparent that more than one possibility is allowed for, although one is more likely than the other or others. It will make the report clearer to those for whom it is written if these are spelled out. As the conclusion will have been reached by assessing the findings against different hypotheses of authorship, it can be helpful to state what these hypotheses are. In many cases, they will be that the questioned writing is by the same person as the known writing or that the questioned writing is by a different person. Each hypothesis produces expectations as to what findings should have been made, and it can also be helpful if these expectations are described. Stating how similar the actual findings are to the expectations from each hypothesis can help to explain how the decision has been reached as to which hypothesis is better supported and by how much it is better supported. The final conclusion is then expressed in terms of how much better the findings support the better-supported hypothesis. How such conclusions should be worded has been the subject of some discussion and research.[5] Whatever conclusion scale is used, it is useful for it to be included in the report so that the court can assess the relative strength of the conclusion.

In any report, the most important factors are that it should be accurate and understandable. There may be good reasons to give an account of the similarities and differences found in detail. If so, it should be done without recourse to unnecessary technical terms. These may sound impressive, and some experts will use them merely because of that, but it is far better for the report to be understood. If technical expressions are employed, they should be explained.

In many legal systems, evidence is allowed to be read if both sides agree. There are advantages in this in that no time is wasted giving undisputed testimony, but some of the impact may be lost if the statement is read by a court officer with no interest in or no understanding of it. To counter this, it is important that the statement be clear, understandable, unambiguous, and incapable of being misinterpreted.

Quality

This chapter and those preceding it have outlined what is universally found in the examination of handwriting and how this can be used to reach conclusions of interest to investigators and courts of law. It is, of course, important that the competency of forensic document examiners be adequate and their methods reliable.

Testing of these methods is carried out in major forensic science establishments and outside organizations, some of whom have reported their results.[6–15] As we move into the 21st century, there is a need to demonstrate to an increasingly demanding society that the results put before a court are reliable. To this end, several organizations have developed standard methods and procedures for use by their document examiners. Both the European Network of Forensic Institutes (ENFSI) and the scientific working groups under the umbrella of the National Institute for Standards and Testing (NIST/SWG) have developed methods against which service providers can be tested. This has allowed independent review of the processes used, and many institutes now boast possession of accreditation standards such as ISO 17025. These standards all require independent quality checking of results and a regime for testing the skills of individual examiners to be demonstrated, all of which should help to increase the reliability and consistency of the discipline. There have also been several academic studies of the performance of individuals, and those carried out by Bryan Found at La Trobe University are of particular note. In a study of disguised signatures by Found et al.,.[12] it was found that forensic handwriting examiners were much more cautious about assigning authorship to disguised signatures than laypersons and consequently are less likely than laypersons to be misled by disguised signatures. Further studies of how forensic handwriting examiners perform in the examination of simulated signatures again suggest that they surpass laypersons in the assignment of authorship and indeed rarely call a simulation as genuine.

Unlike other areas of forensic science, handwriting comparison can be attempted by laypersons who, in any case, regularly recognize writings of relations, friends, and colleagues. Judges, magistrates, and juries rightly lack confidence in deciding whose handwriting is on a questioned document without expert help, and it is therefore important that they be able to separate the expert from the charlatan. The trend toward a more structured quality regime will allow judges to make a better estimate as to the credibility of the witness, but in the end, no system will be able to say whether the expert has gotten it right in the specific case in front of the jury. Evidence given by experts in forensic handwriting comparison can demonstrate the reasons for the conclusions given, but the ultimate test will be by cross-examination. This can be done to a greater extent than in other areas of forensic science, as the evidence is more easily comprehended. This is dealt with in more detail in Chapter 11.

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Handwriting
The Collection of Samples
5

Introduction

In the previous three chapters, the technical aspects of the comparison of handwriting and its principles and methods were discussed. Here, consideration is given to what document examiners need in order to carry out their work effectively in the comparison of handwritings. Adequate authentic writings are vital to a successful examination.

Known Writings

The major use of forensic examination of handwriting is the comparison of the questioned writings with those known to be by certain people. The term universally applied to writings known to have been made by a particular person is “known writing.” The epithet “known” is transferred for convenience of expression from the writer to the writing. The acquisition of these standards may pose a number of difficulties to the investigator.

There are two essential requirements before any material is of use as a standard or specimen of known writing. One is that the writing must be adequate in quality and quantity for the examination to be carried out, and the other is that it can be proved to be by the person to whom it is attributed. Depending on the circumstances of the investigation, it may be easy or difficult to fulfill these conditions.

Request Specimens

In criminal investigations, the suspect can be asked to provide samples of his or her handwriting. In many countries, the suspect cannot be forced to do so, but may well decide that to refuse would not be for the best. It is common in the United Kingdom for people questioned about certain offenses to give specimens without any objection. In these cases, no doubt exists about the origins of the writing; the police officer or investigator who takes them can authenticate them as having been made by the particular person.

When samples are taken, there are two essential and easily remembered principles that have to be observed: it is necessary to compare like with like, and there must be adequate material.

Like with Like

Comparisons are made of each letter of the alphabet with other examples of the same letter. Nothing is gained by comparing the letter *a* with the letter *k*. Similarly, there is no purpose in comparing a block capital *A* with a lowercase cursive letter *a*. Because each letter has to be compared, it is important that all those present in the questioned writings be represented in the known writings. It is also important that figures not be forgotten. They, too, can provide useful evidence.

Besides the presence of actual letters in both writings, there is an advantage in comparison of other factors such as the joins between the letters, the spaces between words and lines, and the layout of the words on the page. The latter includes the spacing of sentences and paragraphs, the size of the margins, and the position of the writing relative to printed words and lines it follows. An example of the importance of layout comes in the writing out of some forms. Where the form provides a space into which a complete entry is written, as opposed to those forms where each character has to be placed in a specific box, the way in which the entry is positioned can vary between individuals. Writings can be started close to the left-hand edge of the area allowed for the entry, or a gap can be left between the edge and the beginning of the writing. When a line is provided for them, writings or signatures may be well above the line or even partly below it; they might stay parallel to it or slope away from or toward it. Because these features might show significant similarities to or differences from the questioned writings, samples taken on a plain piece of paper with no guiding marks may lose some points of useful comparison. In these circumstances, samples taken on a similar form will include information about how the writer arranges entries.

Adequate Material

The quantity of writing available for comparison is also of great importance. It is important to have adequate material, and it is easy for samples to be taken that do not provide this. Writings of one person are variable, not only because deliberate or accidental causes exist, but because human beings are not able to produce consistent results in the execution of such a complicated exercise. If adequate writings are not taken, the questioned writing may show what appear to be significant differences. Some writers use more than one form of a letter as well as a considerable variation in the proportions of a single form. If several examples of the subject's writing are available, there will be plenty of opportunity for the whole range to be exhibited. Writing given at the request of an investigator cannot, of course, contain all the variations used over a period in all the various conditions in which the person can write. Nevertheless, there may well be sufficient material in the samples for strong evidence of common authorship to be found or for significant differences to be shown.

Taking of Samples

When samples of writing are taken, it is necessary to obtain adequate amounts of usefully comparable writing. Too little can be taken, but it is impossible to take too much. The subject should be asked to write the same wording as that in question in the same style of writing—block capitals, cursive, or disconnected script. They should be asked to write the required passage at least 5 or 10 times. The pen used could play some part in the quality of writing, and certain writing instruments should be avoided, such as fiber-tipped pens, which tend to make a rather wide line. A difficulty with this type of pen is that the ink of one line will sometimes merge with that of a line just written, which makes it hard to determine the movement of the pen when the writing is examined. The ballpoint pen is the most widely used instrument and is the best for taking samples. For the most part, the structure of the writing will be clear, and the subject will find no difficulty in using it. If the questioned writing is written with a particular type of pen, that type can be used for some of the samples, but samples should also be taken with a ballpoint pen.

There are occasions when it may be necessary not to disclose that the particular questioned writing is under investigation so that its wording cannot be copied. In these (rather unusual) cases, it is useful to prepare a paragraph of sufficient length to contain the same letters or, preferably, words of the questioned writing. A more convenient method is to reproduce sections printed in a newspaper. Provided that a long enough passage is written, most, if not all, of the letters of the questioned writing will be in the samples. If figures are an important part of the writing, the sports or financial pages of the newspaper will provide a source for them.

There is a temptation to use the phrase "The quick brown fox jumps over the lazy dog" because it contains all the letters of the alphabet, but there is likely to be only one capital letter in the sentence. It may be of some use for samples of block capital writings, but generally, it is inferior to the use of the same material as that in question. One passage to be avoided is "Now is the time for all good men to come to the aid of the party." There is little to be said for this. Again, it does not contain more than one capital, and a number of letters—*b*, *j*, and *k*, for instance—are missing. In both passages, there is no opportunity to write numerals or other characters, such as ampersands. Other passages have been devised to contain all the letters of the alphabet, both in capital and lowercase form, several times. These tend to be rather lengthy but have undoubted value in their completeness. It most cases, however, like with like is the best policy, and the wording of the questioned document provides the most suitable material.

Avoidance of Disguise

The person who is asked to give samples will sometimes think that if he or she disguises his or her writing, he or she will confuse the expert making the comparison; on some occasions, people will attempt to deceive the examiner whom they have engaged. People are variable in their ability to disguise, and those who are not good at it provide few problems for the examiner. Others, however, can make their writing sufficiently different by introducing features that might also be found in the writing of another person. It is therefore advisable to avoid or counteract disguise if possible.

To change natural writing consistently requires concentration, and this is more difficult for longer passages than it is for short ones. Therefore, when samples of writing are taken, a reasonable quantity should be obtained. Earlier, the questioned wording written 5 to 10 times was recommended. If disguise is suspected by the investigator—and an unusual slowness or rapidity of execution is evidence of this—10 or more samples should be taken. Another precaution is to remove the pages of samples as soon as they are written. Disguise is more effectively maintained if the altered forms chosen are copied from examples already written. Concentration can sometimes be broken by a request for a sample of writing that is not described as such. The subject can be asked to write their name and address and the date. They may then forget to apply their disguise. Although this may not provide much material for comparison, it may provide evidence that disguise has taken place in the main sample.

Other reasons may exist for the samples given on request to be unnatural; the subject may be nervous or uncomfortable. Steps should be taken to prevent this happening. There are two reasons for this apart from considerations of dignity and courteousness. First, the most natural writing produced by the subject sitting comfortably is the most useful for the proposed comparison. Second, differences introduced deliberately might later be attributed to other factors. It is of value to be able to refute this as much as possible.

The wording of samples should be dictated to the subject. On no account should the questioned document be put in front of the writer for them to copy. Similarly, the wording should not be written by the investigator and given to the writer to copy. This will give them the opportunity to effect a disguise by copying not only the wording but the writing itself. Typewritten or printed text can be used as a source from which the written passage can be copied, but, again, the style of the typeface could be imitated. The preferred method is that of dictation, even if it takes the investigator more time than other methods would. The proper taking of samples is one of the most important facets of an inquiry involving handwriting, and it is well worth giving the attention needed to do it properly.

In cases where the subject is suspected of forging a signature or other writings, the samples taken should be of the name of the signature or of the wording of the questioned writing. It is pointless to try to get so close to the circumstances of the crime that the subject is asked to simulate the signature or other writing. The attempt is hardly likely to be authentic. Samples of their natural writings could be of value for comparison with those places where the copying of the genuine writing is not accurate. This is rare for signatures and more common for longer writings.

Samples of Writing of the Target Writer

In cases where writing has been copied, it is important to take samples from the person whose writing has been targeted. This is clearly necessary to enable the examiner to compare the suspected simulation to what it should be and to look for significant differences in line quality and structure. In these cases, samples will be expected to be free of disguise; it is not likely that the victim of a forgery will obstruct the investigation.

Not every case of this type is recognized as such at an early stage. In one case, the report that the writing on a check was different from that of the suspect surprised the investigator because he had strong evidence supporting his suspicion. A second check appeared on which the writing was also different, both from that of the first check and from that of the suspect. When the writings of the owners of the checks were obtained, the position became clearer. A good copy of the writing of the owner of the check as well as the signature had been made in each case. Although it did not indicate that the suspect had written the checks, the evidence from the handwriting had not excluded the suspect.

In court matters, when one side suspects or seeks to prove that a document was written by a particular person, the other side may argue not that anyone else may have done it, but that one person, or one of a few, was responsible. It is worthwhile, therefore, to anticipate this situation and test the hypothesis first. Samples of writing of those not suspected but who are possible perpetrators of the crime should be taken if their number is limited. This policy sometimes has surprising results. It is not necessarily the suspect who is found to be responsible. Recipients of anonymous letters, for instance, are sometimes the senders.

Course of Business Writings

It is not always possible to obtain suitable samples of writing of the people involved in an investigation by simply asking them to write whatever is requested. They may be dead, ill, or otherwise unavailable; they also may be unwilling, or willing but able to disguise effectively. In any case, the writings obtained on request may not represent the range of which each subject is capable. There are other sources of writing, made in normal day-to-day activities, that will suffice and perhaps be better than samples given by dictation. These, referred to as "course of business" or collected writings, can play an important part in the enquiry and any subsequent hearing.

Sources

There are many sources of business writings. Not all of them will be available in any one case, and in some it will be impossible to find any. Police officers have greater powers than private investigators and are in a better position to search for what is required. Examples of sources that have been used in criminal cases are passport applications, driver's license applications, job applications, letters, diaries, account books, claims for lost payments, previously written checks, witness statements, and bail forms. In many cases, course-of-business writings may be available only in scanned images on a document management system, but these can still be useful for comparison purposes.

Signatures

Signatures are an important source of known writings written in the course of business. A wide variety of these, written without the knowledge that they may be later used as comparison material, gives a better indication of the range of variation used by the writer than a small sample taken in one sitting. The documents listed previously will provide useful sources for signatures, which can also be found on charge sheets, labels on exhibits, credit cards, and driver's licenses.

In some cases, writings on documents that are themselves the subjects of offenses are admitted by a suspect or are seen by a witness to have been made by that person. These can be used for comparison with further documents. An example of this would occur if a person were witnessed while writing a fraudulent loan application form. One loan in itself might be regarded as a minor fraud, but later, other loan application forms may come to light, all bearing the same writing. The comparison of this witnessed writing with that on the other forms will be of value in establishing that a much more serious fraud has taken place.

Sometimes writing a signature accurately is assiduously practiced, so that no great effort is needed to get a reasonable likeness. In these cases, although comparison is not of natural writings but of simulation with simulation, useful evidence of a single writer can be obtained. If another person copied the same signature, the result is likely to be markedly different even if both were similar in overall appearance to the signature of the owner.

The practicing of simulated signatures can provide important evidence. Attempts to get the simulation right are sometimes found by the investigating officer. Document examiners may be asked to comment on these in court. If they can establish them as simulations, they can advise the court of their likely purpose. The court will be able to assess the significance in the light of other evidence.

Verification of Course-of-Business Writings

Course-of-business writings taken as known writing for comparison purposes have to be established as such before the evidence is of any value to the court. It is not always written by the person who is most obvious. Sometimes a letter apparently by a man will be written by his wife. On occasion, one person will write a letter for another to sign. In other cases, it is clear from the content of the form or application who has completed it. The subject of the inquiry should be asked if the writing to be used as course-of-business known writing is theirs. It will often not occur to subjects to deny it; to do so might appear rather foolish if it is clearly by them. Nevertheless, their verbal admission will be of assistance to the court.

Care should be taken to ensure that the known writing is not by its nature inadmissible in court. References to previous offenses may be disallowed because the jury could be influenced by them. Similarly, writings that are themselves the subject of previous offenses already dealt with may not be allowed for the same reasons. Letters from prison will indicate a previous conviction or that the accused is remanded in custody. In these cases, it is sometimes possible to use the writing without revealing its source. If illustrative charts are used to demonstrate the findings of the expert, the writings can be shown to the court without the context being revealed.

Request and Course-of-Business Writings

In both request samples and course-of-business writings, there are advantages and disadvantages. Request samples can be easily proved to have come from the person in question, they can be of the right method of writing, and they can contain the right letters and words. They can, however, be disguised or refused, either completely or after only a small amount has been written. On the other hand, course-of-business writings may be difficult to associate with their writer with a degree of certainty sufficient for a court to be satisfied, or they may be of the wrong type of script—for example, block capital instead of cursive writing. Their advantage is that they are likely to be natural, without any disguise, and possibly large in quantity. There is nothing to be gained by debating whether request samples are better than course-of-business writings; in most investigations, it is much more useful to obtain both. In this way, it can sometimes be shown that the request samples are disguised when this was not previously suspected or certain. By a comparison of the two sources, sufficient similarity may be found to show this, despite the differences caused by deliberate deception. This sample-to-sample comparison can be of value where the origin of course-of-business writing is not able to be proved. It may be that it provides a link between the questioned writing and the disguised request samples. It is possible in certain cases to link two writings only by comparison with a third. There may be insufficient usefully comparable material between the two pieces of writing, but when each is separately compared to a third, larger sample, there is enough in common to establish a common writer. Request and course-of-business writings are therefore complementary.

Further Reading

Bohn, C.E. Admissibility of standard handwritings, *Journal of Forensic Sciences*, 10, 441, 1965.

Typewriting and Typescripts

6

Introduction

There are two main categories of printed document that the document examiner is likely to encounter: commercially printed documents such as passports, driving licenses, security documents and money, and those documents printed within an office or home environment. The difference these days is essentially the scale of production. Laser printers, inkjet printers, photocopiers, and other technology designed for operation in an office tend to be limited to hundreds of copies with cost related to volume; commercial printing is capable of producing many thousands of documents at marginal cost once the initial setup is achieved. While the overlap between these is considerable and the margins blurred, we have dealt with both variants in Chapter 8. Before considering this, it is helpful to look back at the examination of typewriting. This is for two reasons: first, it introduces a number of concepts that are still present in electronic documents and modern printing such as variations in typeface, and second, typewriters are still encountered in historic documents and it is important to retain the skills and knowledge required for this.

Typewriting

Typewriters have now been in existence for well over 100 years. After initial experimentation in manufacture, a standard form of typebar machine evolved and it can still be found in use today. Alongside these basic models, different and more advanced designs have been introduced, and some have become obsolete.

Electric typebar machines, those using interchangeable single elements in the shape of spheres or wheels, electronic typewriters, word processors, and computer-controlled printers have given variety to the means of printing characters on paper in the home or office.

They can be used in circumstances of criminal activity or those of interest to civil courts, and the typed document can provide, over and above the content of what is typed, evidence of value to the investigator or court. Knowledge of the make of machine suspected of being used to prepare a document may assist a police officer in locating the actual typewriter. A court may find the fact that two documents were made by the same machine, or that a particular typewriter was used to type a letter, is very significant.

The document examiner, using the scientific principles of observation and deduction, applying the appropriate tests, and comparing the results with the background corpus of knowledge on the subject, can provide answers to many of the questions asked by his or her clients.

The most significant features of typewritings of interest to the examiner are those that can be adduced from the document itself, the style and shape of the individual characters, and the spacing between them. These and other factors are considered in this chapter together with the methods used to examine them.

Methods of producing typed material have changed radically over recent years. Now, computer printers have largely replaced typewriters, but the latter are still sold, and many veteran machines are still in existence. Because they still feature occasionally in the work of forensic document examiners, descriptions of methods for testing their output are retained in this edition.

Typeface

For many years, a general style of typeface was adopted by typewriter manufacturers, but within this style were differences in size and design. Some differences found between the products of different makers are fairly large, and others are more subtle. Typical of the larger variations are numerals, which can include figure *2*s with or without straight bases, *3*s with flat or curved tops, and *4*s that are either open or contain an enclosed triangle. Capital letters *M* and *W* can be made with the center extending to the whole or to half the height of the letter. Smaller differences found in lowercase letters include the shape of the bottom of a letter *a* and the length and position of the cross bar over the letter *t*.

There are other styles that differ more radically. Typical of these are "shaded" characters, which have differences in the width of the lines making up the letter; "cubic" designs, with rectangular shapes with rounded corners rather than circles; and designs resembling cursive handwriting.

All these designs can be mounted on typebars, moved manually or electrically, or on single elements, colloquially called "golf balls" or "daisywheels" because of their appearance. These are easily removed from a machine and can be replaced by another using a different style.

Originally, the typeface was designed and made by the manufacturer of the typewriter. Now, it may be supplied by a specialist producer for the manufacturer of the machine. Similarly, type wheels are often not made by the makers of the machines.

Letter Spacing

Typewriters require a mechanism to ensure that the letters are properly spaced. The most common spacings are those where there are 10 or 12 letters in an inch of typewriting. It is common practice for document examiners to refer to spacing not in characters per inch but as the length occupied by 100 characters. Thus, typewriters that print 10 characters to the inch, often known as "pica" machines, have a spacing of 254 mm per 100 characters. Those with 12 characters to the inch, referred to as "elite" typewriters, have a spacing of 212 mm per 100 characters. Similarly, other machines use spacings of 185, 200, 210, 220, 225, 230, 236, 250, and 260 mm. These can be found in manual and electric typebar machines as well as in single-element typewriters.

Proportional spacing machines are based on units of spacings where letters occupy two, three, four, or five units, depending on their width. The units are typically 1/32 or 1/36 of an inch, producing results approximately equivalent to pica and elite spacings. More recently, word processors and electronic typewriters have brought right-hand justification to typewriting. This practice, normal in printing, varies the spacing so that each line begins and ends exactly below the one above. This is achieved by adding the required number of extra spaces between words in the line or adding a fraction of a space, spreading the added spacing evenly between the words on the line.

Typeface Collections

It may be of value to an investigator, when faced with a document bearing typewriting, to have some indication of its source. It may be useful if the make of the typewriter is known, particularly when confronted with a large number of machines in one building or room. It is therefore useful for document examiners to have a collection of the typefaces of many different machines together with a system of classification that enables them to find the style that corresponds to that of the typewriting on the questioned document. The collection will also be of value as background information when a comparison of typewritings is made between questioned material and that of known origin.

A further advantage in ascertaining the make and model of the machine is that dating of a disputed piece of typewriting might be possible. If the date when a particular style or combination of style and spacing was introduced can be obtained from the manufacturer, it can be shown whether a document could have been typed at a particular time. Systems such as the HAAS atlas, based on differences in typeface and spacing, are used throughout the world, mostly by police forces or government agencies working in the investigation of crime. While the collections these days are managed using computers, the final comparison is made with hard copy of the type styles in the collection.[1]

A system was produced by the International Criminal Police Organisation (Interpol). Cards containing the type styles are sorted in order of letter spacing and features found in certain letters and numerals. Similar information can now be found at http://typewriterdatabase.com.

These systems enable the manufacturer as well as the model of the machine to be identified. However, as was discussed earlier, not every typewriter maker produces its own typeface. Some use a typeface produced by a specialist manufacturer, such as Ransmayer in Germany, so there is a possibility that more than one company will use the same pattern. Similarly, printwheels are made by specialist manufacturers, and the same considerations apply. A further complication arises with some type ball machines that can use elements made by another typewriter company. This interchangeability of single elements will confuse an investigator who is looking for a particular brand name on all the typewriters that are possible sources of the typewriting in question.

Confusion can also be caused by mergers of companies in the office machinery business. Although the type style of a particular manufacturer may be unique to the company, the machines may be issued under different names. Olivetti and Underwood are two firms that combined, so much of the typeface found under one name is also found under the other. Similarly, the names Adler, Triumph, Royal, and Imperial were part of the same multinational group, and the same machines using the same range of typefaces and spacings will be found under all these names. In previous years, these companies were independent, and their styles could be distinguished. It is therefore possible that the typewriter responsible for the material in question could be overlooked if the investigator is concentrating on one or two names and excludes those he has not been given. Care must therefore be exercised to avoid the rejection of a machine because it bears the wrong name.

Linking Typewriting to a Machine

The most important evidence that can be deduced from the typescript on a document, apart from the information it conveys, is the identification of the actual machine that was used to type it. Clearly, this is of great significance in the investigation of a series of events or in a trial in a civil or criminal court. Any comparison made is normally of like with like, typewriting with typewriting. This is not always the case; a quick comparison can be made with the typeface on the machine. If clear differences are found, say a flat-topped 3 on the machine and one with a round top in the document, the typewriter or type element can be eliminated before any sample is taken. If no such difference is found, typewritings must be made to enable a more detailed comparison to be carried out.

When considering the comparison of typewritings, important points have to be borne in mind. In the typebar machine the typeface and the typewriter are to be regarded as one. In single-element models, whether type ball or type wheel forms, there is both a machine and an element component in the typed material, so that what is found is a combination of the two. If all typewriters were made to a standard of absolute perfection that was maintained as long as the machine was in operation, the results from the comparison of their products would be of limited value. A style could be identified, and the typewriting could be attributed to any one of a large number of machines. This is not found in practice. Variations from perfection are present in typebar machines, in the type elements, and in the mechanisms of typewriters using those elements.

Although every manufacturer maintains quality control over its machines, there will be tolerances within which there will be discernible differences. These may be too small to be of forensic significance. In many comparisons made in forensic science, one source will produce variability. If this variation is as great as the differences found between sources, no significance can be placed on a comparison. Many of the small variations found between typewritings from different machines are no greater than those found from one machine. Of greater significance are those features that develop during the lifetime of a typewriter—faults that occur from wear or damage. It is because these occur for the most part randomly that they are different for different typewriters.

Typewriter Faults

There are a number of ways in which imperfections occur that will be apparent in the typescript. The first is damage to individual characters. The metal type can be chipped or bent in use, especially when two keys of a typebar machine are depressed together. The resultant collision between the two components can cause damage to one or both of them, and this will show on subsequent printed impressions. Damage is less prevalent in type ball machines, but small molding defects can occur in manufacture, and these can appear on a typewritten page. Print wheel characters are also prone to damage, but, unlike distortions of the metal type of typebar machines that, once made, can remain unchanged indefinitely, the plastic material of type wheel elements deteriorates rapidly once its hard surface coating has been broken.

A second fault found in typewriters is misalignment of certain characters. When a typebar machine is manufactured, the type metal pieces bearing the characters are soldered onto the ends of the bars. The consistency with which they are affixed is not perfect, and this results in small differences in the positioning of the printed characters relative to each other. Later, if a typebar is twisted or bent, the impressions made by the characters on that bar will be misplaced. The divergence from the ideal position can be upward, downward, to the left or right, at an angle, or a combination of two or more of these. Also, twisting will produce an uneven image. The character may be more heavily printed on one side than on the other, or heavier at the top or the bottom, depending on the distortion of the typebar. Looseness of the mechanism can produce variable results on the paper, with characters sometimes properly aligned and at other times out of position. In some machines, there is considerable variation in the positions of all the keys, so that no consistent misalignment of a single character can be discovered.

In type ball machines, the movement of the ball in both a horizontal and a vertical direction will determine which character is printed. The mechanism that rotates the ball in either plane can be out of adjustment because of wear or damage. This will result in either a horizontal row or a vertical column being out of position at the time of printing. When this happens, all the characters on the row or column are misplaced to the same extent. This feature is produced by the machine and will still be found if another type ball is put in. Damage to one of the teeth on the base of the element, the function of which is to position it properly with the mechanism of the machine, will also misplace a vertical row of characters. If the element is changed, the misalignment will disappear; if it is used on another machine, the same defect will occur again.

With print wheel machines, misalignments also occur. The spokes of the wheel may become distorted, giving displacement of the character. Unlike the conventional typebar machine, only one character will be out of position when this happens; only one is present on each spoke or "petal." Preliminary examination of some electronic daisy wheel machines suggests that their spacing is very consistent within machines and varies somewhat more between machines. The causes of the differences appear to be in the machines as well as in the element.

Other Faults

There are other ways in which less-than-perfect results are obtained from typewriters. The characters may be dirty, so that what should be an unlinked circle in a letter is printed as a solid one. This is clearly a temporary condition that can be easily corrected by cleaning. The shift key mechanism can move too far or not far enough, resulting in capital letters and other characters being higher or lower than they should. The mechanism holding the paper may be loose, so that the lines of typescript are unevenly separated. The platen may be out of position, making all the characters print heavily at the top or bottom. The mechanism that moves the platen to space the letters can "misfire" occasionally, giving either a gap between characters or two letters crowding on each other. In electric machines using typebars, the adjustment for pressure of one or more characters may be different from that of the rest, so that they print consistently more heavily or more lightly. The alignment of the ribbon in the typewriter might be defective, cutting off either the top or bottom of all the characters, as opposed to damage of certain individual typefaces or a mixture of black and red typescript if a dual-color ribbon is used.

Comparison of Typescript

To reach a conclusion on typewritten material requires careful and accurate comparison of the known and questioned typescript. The terms "known" and "questioned" refer, as in handwriting comparisons, to the origins of the material being compared. Known typewritings are those whose source is established either by other evidence or by the fact that they have been made by the investigator or the document examiner using the typewriter that is the subject of the inquiry, perhaps the property of the defendant in a criminal trial. The questioned document is the one of disputed origin. In some cases, it is necessary to compare only questioned documents with each other.

Methods

Comparison of typescripts can be performed in two ways. The first, as in the comparison of handwriting, is simply to observe the two documents side by side, noting each letter, figure, comma, question mark, pound or dollar sign, and all the other characters present to see if they match. At the same time, imperfections caused by damage are noted and compared. Observation is made of any clear misalignments present, and their consistency and the results are noted. The whole picture, of similarities, significant features, differences, and variables, is assessed and a conclusion reached. This is in many cases an adequate procedure for the purpose. In many comparisons, the within-sample variation is quite considerable, caused by looseness in the mechanism of the typewriter, variation in the quality of the ribbon, and factors introduced by the typist. The features of significance noted in a side-by-side comparison are often sufficiently large to be compared accurately and noted so that conclusions can be arrived at properly. A more finely tuned examination would not necessarily reveal any more information other than the "noise" of variable factors of no significance, but where such an examination is necessary, the use of specialist spacing grids can assist. These take the form of transparent plastic sheets marked with regularly spaced parallel vertical lines specially designed to fit the spacing chosen by typewriter manufacturers: 2.12 mm, 2.54 mm, 2.60 mm, and others. The position of the character relative to the grid lines gives a clear indication of the correctness of its alignment.

Comparison of Images

In addition to careful observation, typewritings can also be compared using high-resolution imaging software so that direct superposition of the images can reveal differences between the images. This was traditionally done optically using comparison projectors such as the Docucenter 4500, made by Projectina AG of Heerbrugg, Switzerland, which projected images of two documents together onto one screen (see Chapter 10). The two documents, when superposed, appear to be one, except where there are differences, which can be shown up by oscillation of the images or illumination of the documents with different colors, such as red and green. Small differences due to different typewriters having been used can be detected; this contrasts with much smaller variations found in the output of one machine.

Before any conclusions are reached from this examination, sufficient samples from the machine in question must be obtained to establish that it operates in a consistent way. If it does not, its own variations may well be as great as those between its products and those of another machine. When the outputs of consistently operating machines are examined, results superior to those of side-by-side observation or by the use of grids are obtained. In these cases, differences in alignment that are too small to be regarded as caused by wear or damage, because they are present on new machines and are therefore acceptable by the manufacturer and its customers, can be detected.

The Significance of Differences

The first task of the document examiner is to discover whether the two or more pieces of typescript are similar or whether they have any clear differences. If differences in spacing, letter or figure design, or other characters are found; if there is damage or misalignment on one sample and not in the other; or if a character, a figure *1* perhaps, is present on a document but is not available on the machine, there is an indication that the two samples do not have a common source. Before eliminating the possibility, some care is needed, because one machine can produce different results for various reasons.

Obviously, if a single-element machine is involved, a change of the type ball or print wheel will give very different results. In some type ball machines, the IBM 72, for instance, there is a facility to print at either 10 or 12 letters to the inch. Similarly, many electronic typewriters using type wheels can produce typescript at more than two different spacings. Another spacing property is that of justification, giving an even right-hand edge to a page of typescript, like that found in printing. Many electronic typewriters are equipped for both this and conventional typewriting.

If faults are found in one sample and not in that being compared with it, a single source is not necessarily ruled out. These differences could have developed over a period, so, if the later sample of typescript has a number of damaged or misplaced characters while the earlier one does not, it is possible that these features developed during the time between the typing of the two documents. If the reverse is true, it is possible that the machine has been serviced and its alignment defects corrected. The condition of the paper may give rise to apparent differences. Creases and folds will affect the dimensions of a document, and differences in humidity can also result in subtle differences in the spacing of the characters.

All these points must be considered before any conclusion that two documents were not typed on one machine is reached. If the machine itself is available, the task will not be difficult. It will be clear if it is a single-element typewriter or not, and any dual or variable spacing capability it has will be apparent. Any replaced type is usually clearly recognizable by a different appearance of the shape of the block or in its soldering to the typebar. If the machine is not available, reference to a typeface collection will help in determining whether the style is found on single-element machines. Despite these considerations, in most cases, differences of style, spacing, and damage are found to be due to a different machine having been used. The same applies if there are clear and consistent differences in alignment of characters.

The Significance of Similarities

When two typescripts are found to match—that is, when all the characters are found to be similar and when the letter spacings, both overall and individually, are the same—there is no evidence that more than one machine is involved. Although both could have been made by one typewriter, there may be other machines that could produce indistinguishable results. This possibility can be ruled out if there are sufficient features present that would not be expected to occur in exactly the same way in other machines. These features are the faults referred to earlier—damaged characters and misalignments. Although any one fault could be found in more than one typewriter by coincidence, when a number occur together, the chances of this become negligible. It is not reasonable to expect that damage and misalignment will occur in the same places in other machines. There are more than 40 keys on a typewriter, each producing two characters, and any one of these can be chipped or bent in a number of a different ways. The odds against the same damage occurring by chance on the same character in two different machines are high, and higher still for two or more such faults. Not every piece of damage or misalignment is evenly probable; some are likely to occur more frequently than others, but studies of faults found in a number of different typewriters have indicated that this basis of identification is sound.

Special considerations have to be taken into account in type ball machines. Here, with characters in rows and columns on the single element, misalignments do not occur randomly. Whereas in typebar machines, a fault in one letter would not make one in another more likely, in a "golf ball" machine, a single feature can affect a number of different characters. If a tooth, part of the mechanism for fixing the element to the machine, is broken away from the base of the ball, there will be a displacement of the four characters of one of the columns on it. These misalignments must be regarded as one fault, not four, and they indicate that any similar ball, similarly damaged, could have been used to make the typewriting.

The mechanism that rotates and tilts the ball to select the appropriate character can produce slightly different results in different machines. The distance traveled is not always exactly the same between different machines. This results in misalignment of a whole row or column of characters. Again, a misplacement of a row or column represents one fault, not several, and is therefore less significant than it might at first appear.

Dating of Typewritings

The significance of differences has been discussed earlier. If they are present in style, or damage or alignment between two samples of typescript, there may be reasons why they do not exclude the possibility of common origin. If two typewritings are similar and have features in common that could not be explained except by the attribution of both to a common source, and if there are certain differences present, the inference is that something must have happened that caused these to occur in the time between the typing of the documents. Such an explanation is the only logical one if all the observations and comparisons are properly carried out.

Features that are present in one sample but not in another can be used to date the preparation of a typed document. If samples of the output of a machine made at regular intervals over a period are examined, the first occurrence of examples of damaged characters can be discovered. If new damage occurs fairly regularly (in some machines, this does happen), there will be a changing pattern of faults. There may be occasions on which it is required to establish *when* a certain document was typed. If it is found that a fault is present in a certain document but not another, the period during which the situation existed can be discovered from the examination of the series of dated documents. Also, if repairs have been carried out, information about the date of typing can be obtained.[2]

The Collection of Samples

The role of the investigator in cases involving the comparison of typescripts is important. The case may require either the identification of the source of the document or the connection of two or more typewritten documents with each other.

In most cases, the acquisition of the typewriter itself is of advantage to the examiner, and ultimately to those to whom his or her conclusion is directed. There are a number of reasons for this. First, it is possible to discover all the characters that are present on the machine. A figure *1* appearing on the document but not in the typeface on the typewriter will be sufficient to rule it out as a possible source of the typescript unless a replacement of the key has been made, and this will show on examination of the machine. If a character is damaged, it will be apparent when the typeface itself is examined, eliminating the possibility that an unusual design could be mistaken for a fault. Other faults, such as imperfect operation of various mechanisms, broken parts, misalignments, and wear, can be detected at the source and reasons for their effects on documents can be determined. The consistency of operation of the typewriter can be tested to discover whether variations are within the range produced by the machine or outside it. Other evidence provided by the ribbon, correcting tape, electronic memories, or other factors apart from the comparison of typescript can be deduced from the machine. These will be dealt with later, but they emphasize the desirability of access to the typewriter rather than merely samples from it. If a single-element machine is in question, any extra elements will need to be taken with the machine itself.

However, when the machine cannot be removed, samples from it should be taken either using the ribbon, if it is in good condition, or a piece of carbon paper with the ribbon control in the stencil position. Provided that the carbon paper is new, this method provides better results and does not destroy any evidence the ribbon may yield. Another method is to replace the ribbon with a new one and take the samples with that. This can be unwise if a heavily inked fabric ribbon is substituted, because it can produce lines that are so thick that they obscure detail, but it is a satisfactory method for "carbon" ribbons, which give a much clearer outline of the characters.

The samples taken should be of the entire keyboard, both with and without the operation of the shift key, so that upper and lowercase letters, all the figures, punctuation marks, and other characters are recorded. As far as is possible, the passage in question should be typed in the same layout as that being compared. This should be done four or five times so that the consistency of the output can be tested. It is important to identify the machine from which the samples have been taken, so the make, model, and serial number should be typed on each. Other material known to have been typed on the machine could provide possible valuable evidence if there has been a change over a period. Letters typed on or around the date of the document in question as well as others typed before and after this date are essential if it is necessary to show when the typescript was made. Variable factors such as dirty typeface and the condition of the ribbon, in addition to the combination of faults that have developed over a period, are important in these cases.

When many machines are possible sources of a typewritten document, the investigator may make a preliminary investigation by examining obvious features like the length of the center of capital *M*s and *W*s, the top of the *3*, and the shape of the *4*. As the typeface is fixed, unlike in modern machines, then a mismatch is likely to indicate that a different machine has been used, or at least a different element.

Connecting Factors Other Than Typescript

Evidence to connect a piece of typescript with a typewriter can be provided by means other than comparison of the typescript. The most important of these is the examination of the ribbon, of which there are various types in use. The first is the fabric ribbon. A strip of ink-soaked cotton or manmade material is struck by the typeface, the image of which is thereby printed onto the paper. The effect on the ribbon is to remove some of its ink, but the letter shape is not, or is rarely, permanently impressed upon it. Instead, the ink flows from around the impression to restore an even distribution. The effect on the typeface is to cover its surface with a layer of ink.

Some typewriters are provided with a mechanism to alter the position of the ribbon so that either the top or bottom half is struck by the typeface. This enables a two-colored, usually red and black, ribbon to be used so that both colors can be employed in the typed document. When the change from a normal black typescript to a red one is made, the red half of the ribbon is struck with a typeface covered with black ink. So, as well as marking the paper with a red image of the characters, the typeface leaves its shape on the red part of the ribbon. The letters typed in red on the document are therefore left on the ribbon. This will apply only for a few strokes, after which the black ink will have been removed from the typeface. The ribbon is designed to move both from right to left and from left to right, so, depending on that movement, the words may be reversed or the right way around.

Correctable carbon film ribbons made of plastic material depend on the shape of the letter being punched out by the typeface and pressed onto the paper. The effect is to give a sharp, black, clear typescript on the document and to leave a gap in the ribbon for each character typed that exactly reproduces the shape of the letter, including any faults that are present. In some cases, the irregular edges of its characters or remaining pieces of the ribbon can be matched with those on the questioned document. As the ribbon moves after each character, the whole passage is recorded on it. Errors that have been typed and then corrected are also present, and underlining is found after the words that have been underlined. The ribbon can thus be identified. The value of this is, of course, great, but because the ribbon has a limited life and is thrown away, the machine has to be discovered before this has happened. There can be another reason for the examination of the punched-out letters: if the element has been removed deliberately to destroy evidence of its existence, the plastic ribbon can show the style of type.

Carbon ribbons are packed in various ways, depending on the model for which they are designed. Originally, a single strip wide enough to take one row of letters was provided. This type is easy to read; the only problem is to discover where each word ends, because the ribbon does not move when the space bar is depressed, so there is no gap between separate groups of characters. Cassettes are now the normal method of containing this type of ribbon because they provide a much easier method of replacement. These are often wider, with each bearing either two or three rows of characters along its length. Reading information from them entails examination of each column of two or three characters across the ribbon, followed by the next. This is a slow and tedious method, but in many cases, it is of great value. The discovery of the contents of a questioned letter on the ribbon provides proof of its use.

In order to speed up the process of ribbon reading, special apparatuses have been developed. One method is to record the information on a videotape,[3] and in another, the ribbon analysis workstation (RAW) records the information, which can be manipulated by computer to rearrange the letters from a format that is difficult to read into a straight line for easy interpretation (http://www.envisagesystems.co.uk/forensics.html).

It is not only on the black or red ribbon used to print typescript that evidence can be left. Some machines are fitted with correcting devices that work by substituting another ribbon that will either remove or cover the typed character. The first type employs an adhesive tape that will remove the letter-shaped piece of plastic that has just been typed. The second punches a piece of white plastic on top of the black character already there. In both cases, the evidence is left on the ribbon: on one as black characters caught on the sticky tape like flies on fly paper, and on the other as character-shaped holes in the white plastic correcting ribbon. Only one or two characters are insufficient to indicate with certainty that the letter has been corrected by the ribbon, but a number of characters in the correct order would be difficult or impossible to find by coincidence.

A similar method of correcting is provided by strips of paper prepared specially for the purpose. These are placed between the paper and the typeface and the incorrect character is typed over the error. The character is thus retyped in white (or another color designed to match that of the paper) so that it covers the mistake, and the correction can be typed over it. With a correction ribbon, the letter is punched out of the paper. If a number of alterations have been made on a single piece of correcting paper, and they also occur in the questioned document, significant evidence is provided. In one case, 12 such characters were found in a letter in dispute and also on a piece of correcting paper found with the suspected machine. The typeface match was without characteristic features, but the correcting paper provided the linking evidence. The odds against the same 12 letters occurring by chance are astronomical.

Ribbon Composition

Typewriter ribbons are temporary fixtures and do not need to be substituted by identical replacements. This means that the fact that the ink of a ribbon in a machine differs from that on the paper does not exclude the machine from being the one used to type a letter. Conversely, because ribbons are made in large numbers to carefully controlled standards, there is little significance in a match. There is therefore little point in comparing the ink or plastic material on the paper with that on another document or in a ribbon on a typewriter. However, there may be occasions where this is of value—usually to determine whether there are differences between two pieces of typescript that should have been typed at approximately the same time on the same machine.

As indicated earlier, there are two basic types of typewriter ribbon, one using ink and the other using a carbon film. The two are clearly distinguishable under low-power magnification. To compare different types of ink, the normal methods of examination of inks described in Chapter 7 can be employed. There is, however, a smaller range of variation in the products in general use than there is for inks found in pens.

A number of different manufacturers produce carbon ribbons, and these can be distinguished on paper by microscopic means. The clearest separation of different types is obtained by using a scanning electron microscope.[4]

Erasure of Typewriting

Typewritten documents, like any others, are subject to alteration. One of the standard methods of correcting typing mistakes is to apply a special correcting fluid, which, when dried on the surface, covers it with a layer of white or colored material, which the correct characters can be typed over. Alterations to a document can be made with this material and can be detected by a number of different methods.

As the paper of the document is likely to be thinner than the layer of dried correcting fluid, the best approach is from the back of the page. Strong lighting, either through the page or directly on it, is necessary. The materials can be made more transparent with the use of a suitable inert, volatile liquid that soaks into the paper and correcting fluid, making it translucent, and does not affect the typewriting. Examination of the soaked area must be made quickly, because the solvent will evaporate rapidly. There is, however, normally time for a photograph to be made, and the process can be repeated if necessary. The document is not permanently affected by this process.

Infrared or visible light luminescence can be effective in determining what has been obliterated by correcting fluid. Some inks may fluoresce and therefore be more easily visible. The laser provides an invaluable source of illumination. This method is particularly useful for ballpoint pen and other inks covered with correcting fluid (see Chapter 7).

Typewritings are also erased by mechanical means, by scraping the surface with a sharp blade or using an especially hard rubber eraser, for instance. Their indentations, examined under oblique light; traces of ink remaining; or a combination of both may be sufficient to identify what was erased.

In some cases, the erased typewriting may luminesce in the infrared or far red region of the spectrum. This appears to be because an invisible component of the ink has penetrated more deeply into the paper than have the visible pigments.

Typewritings made with carbon ribbons adhere to the surface of the paper and do not penetrate further. They can be removed with less abrasion than that required for typewritings made with inked fabric ribbons. This is especially true for those designed to be corrected by being lifted off with an inbuilt adhesive tape. The indentations remaining after characters from carbon ribbon have been erased can provide a means of identification of what was erased.

Other Examinations of Typewritten Documents

Besides the need to identify the make of machine or the particular machine that was used to make a questioned document, there are other questions for which the investigating officer or a court may require answers. The date when the typewriting was made, whether part of it was typed later than the rest, and who typed it are all the subject of enquiries directed to the document examiner.

Dating of Typewritten Documents

As with most dating problems in document examination, there are often difficulties in finding a solution. Apart from general considerations such as that the type style or ribbon had not been produced before a certain date, little can be done. As discussed earlier, progressive damage to different characters can be of assistance, but the typescript itself does not change in any detectable way over a period unless subjected to some form of damage.

The best methods of timing are those where some reference is made to marks elsewhere on the paper. Folds, holes, or writings made before the typing will affect the printing of the characters in a way different from those when the typewriting is already on the paper. Typewriting made over a crease will not give an even coating on the rough edge of the broken fibers but may, when examined under a microscope, appear broader and more deeply ingrained into the paper. Such differences are not very marked in contrast to written strokes, and it is advisable to make test examples of typewriting before and after creasing to ensure that it is possible to distinguish between them. The sequencing of typewriting made over writing in wet or ballpoint ink can often be achieved with certainty. This is dealt with in Chapter 9.

Added Typescript

Another method of determining the timing of two pieces of typewriting on the same document is in testing the consistency of alignment. It is sometimes alleged that a piece of typewriting was not present on a document when it was first seen, perhaps when it was signed. The suggestion is that it was added later for the purposes of deceit. To add extra typewriting to that already there, the paper has to be replaced in the machine and accurately aligned both vertically and horizontally. This is not as easy as it sounds. Although care will be taken to make the added portion appear in the correct position, it will be difficult to ensure that it is exactly aligned. The apparatus of the document examiner, grids and methods of accurate measurement and magnification, together with the greater ease of examination of a document in laboratory conditions compared with estimation of alignment in a typewriter, are methods of discovering the evidence that this difficult task has been attempted.

To examine typewritten documents for this evidence, the grids used for testing of the alignment of individual characters are invaluable. The main body of typescript is covered with the grid so that each character on a line is in position in its box, with most of them centrally placed. Other lines will fall into place, or, if half spacing is employed, only alternate lines will be accurately positioned. Examination of the questioned passage will show whether its characters fall into the correct places in the grid.

Problems can arise if the document is creased. A fold can reduce the length of a sheet of paper and give the appearance that typewriting below it is out of alignment. This must be allowed for before any conclusions are made.

Identification of a Typist

There are a number of different typing methods taught in business schools. These change with fashion or because of technical developments, and, like styles of handwriting, will allow individuality to be applied to the basic pattern. There will therefore be a wide variation in the way a letter is typed. The spacing of lines, the size of the margins, the depth of indentation at the beginning of paragraph, the number of spaces after periods or commas, and the use of capitals are all variable and might be consistent for one typist. The touch of the typist can give an indication that he or she made the typewriting in question if this is made with a manual machine. This is particularly of value in those exceptional cases where a very heavy pressure has been used, sometimes to the extent that periods and the letter *o* are punched out of the page.

All these factors will not be unique, even considered in combination, and will be related to how the operator was taught. They may, nevertheless, give some indication as to who may have made the typewriting, or, conversely, who is unlikely to have done so. A person with no training in the proper methods of laying out a letter is unlikely to be able to create a well-produced piece of typescript. Indications that a professional typist or one who is well practiced has prepared a document may also be given if there is an absence of mistakes, or by the use of a small *l* for the figure *1* when that figure is present on the keyboard.

It is from the errors that are made that some indication of common authorship of two pieces of typewriting may be given. The figure *1* may cause problems for the infrequent typist, who is quite likely to use a capital *I*. A similar frequency of errors, for instance, forgetting to space words correctly, using capitals in the wrong place, and other unusual factors, may be found in two pieces of typewriting. There would need to be a number of such features before any conclusion was stated that the two documents were typed by one person. Many mistakes made by the amateur typist are shared by those of similar lack of skill. Some errors are particularly common, so the possibility of coincidental match cannot be ruled out.

However, in a limited population, the evidence may be sufficient to pinpoint only one or two people who are likely to use a particular style of production. Of course, it would be possible for another person to disguise his ability or to copy the errors of another person, so, as in any other investigation, all the possibilities have to be considered.

Comparisons between known and questioned typewritings to determine the identity of the typist are best made by using previously typed material that can be shown to have been made by the person suspected. It is difficult to take samples of typewriting on request.

Spelling mistakes, frequent use of certain words, unconventional punctuation, and similar features of the style of composition that may indicate a particular writer are also of value. The dividing line between these and the characteristics of text analysis is not clear. The latter is an area not normally considered as being within the expertise of the forensic document examiner. In any case, such analyses require far larger passages than those usually encountered in the comparison of typescript. This is dealt with more fully in Chapter 2. Document examiners acting as experts in court must keep to those factors about which their experience and background knowledge enable then to comment. As in all their work, it is by reference to their background corpus of knowledge that they are able to make decisions on the findings in any particular case.

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The Materials of Handwritten Documents
Substances and Techniques

7

Introduction

In writing this chapter, we have returned to the central theme of this book, which is to produce an easily accessible text for those encountering forensic document examination in the course of their work, particularly within a legal context. The substances from which documents are prepared and the techniques that are used to test these materials are considered. It is possible only to describe in outline the makeup of paper, inks, and other materials; discussion of the principles of the methods of their examination is also brief, but special processes and the apparatus required for their application where they are specific to document examination are dealt with in Chapter 10. Where techniques are of more general use, then references to relevant texts are supplied. For further reading, a recent comprehensive review of all the techniques for the analysis of the materials used in the production of documents, covering writing inks, printing inks, paper and intersecting lines, has been written by Calcarrada and Garcia-Ruiz[1] and is recommended.

The purpose of analyzing any material used in the production of a questioned document, such as an ink or a piece of paper, is to compare it with another material elsewhere in the questioned document itself or on another document to determine whether they share a common origin. There may also be a need to provide intelligence information for the investigator about the possible origins of the document. While from an intellectual point of view it is interesting to know exactly what a material is composed of, it is not usually necessary or relevant to the case and is extremely time consuming to determine. As a consequence, we have restricted ourselves to a limited discussion of the techniques and concentrated on the results that may be produced and how they might be interpreted.

This chapter concentrates on writing materials such as inks and paper, while photocopy toners and printing inks are covered in Chapter 8, and typewriter ribbons are referred to in Chapter 6.

Light

Many of the techniques employed to distinguish between paper or inks involve the use of light, or, to be more precise, electromagnetic radiation, so it is helpful to have a basic understanding of this. The techniques most commonly used by document examiners are referred to collectively as "filtered light techniques"; they can be viewed using simple combinations of light sources, filters, and cameras, but often they are combined into more sophisticated and easy-to-use equipment such as Foster and Freeman's video-spectral comparator (VSC). How the techniques are used in practice for a particular material will be described in the subsequent text, but a simple description of the principles is supplied below.

Electromagnetic radiation encompasses a spectrum of radiation from radio waves, which may have a wavelength of thousands of meters, to x-rays and gamma rays, which have extremely short wavelengths. As document examiners, we are interested only in the wavelengths of radiation in or near the visible region of the spectrum. Light is conventionally the radiation we can see (visible spectrum [VIS]), usually between 400 (blue light) and 700 nm (red light); we will also encounter long-wave ultraviolet (200 to 400 nm, just outside the blue end of the spectrum), and near infrared light (700–1000 nm, just beyond the red end of the spectrum). Ultraviolet (UV) is higher energy than blue, which is higher energy than red, which in turn is higher energy than infrared (IR). Thus, a shorter wavelength equates to higher energy.

Examination of Color

Light is essentially electromagnetic radiation of certain wavelengths or frequencies that can be detected by the eye, and different people will be able to see a slightly different range of light. For convenience, we have defined visible light as between 400 and 700 nm. Not only can the eye detect the radiation, but it can distinguish between the wavelengths present. Thus, if light with a wavelength of 550 nm strikes the eye, it is recognized as yellow light, whereas if the radiation has a wavelength of 450 nm, it appears blue. The eye is sensitive to radiation ranging in wavelength from about 400 to 700 nm (but the wavelengths can vary a little from person to person) and sees the spectrum in colors ranging from violet to red, as in a rainbow.

The eye sees a combination of the colors, not the individual wavelengths. If a mixture of two wavelengths impinges on the eye, a third color will be seen. A mixture of red and green light will be seen as yellow, a color also seen when monochromatic light at a wavelength between those of red and green light is detected. A demonstration of the range of colors available from using only three primary colors—red, green, and blue light—is daily seen in the natural hues appearing on a television screen. Even white light can be created from these three colors. The industry tries to standardize color using the proportions of red, green, and blue light required to match the color (e.g., purple might be 0.5R + 0.0G + 0.5B).

Absorbance

Sources of light are rarely monochromatic—that is, of one wavelength. Sunlight or the radiation from a conventional electric light bulb contain wavelengths in the whole range, and their combined effect on the eye causes it to see a white light. Objects that appear white reflect all light. If white light falls on an object before reaching the eye and part of the light is absorbed, the object appears colored. The eye sees only the reflected light, not the portion that was absorbed. Thus, if the object were a red snooker ball seen in the sunshine, only the red light would be reflected and the rest of the light (the blue, green, and yellow components) would be absorbed, so the ball appears red. If all light is absorbed, the object is black.

Illumination by a single wavelength or a narrow band automatically eliminates other colors; a red sweater is not seen as red under a sodium street lamp, but orange—there is no red to reflect.

An object has a particular color because certain compounds within the object absorb light at particular wavelengths. They do this because they have in their structure combinations of atoms, called chromophores, that have this property, and these do not absorb a single wavelength, but a range or ranges of wavelengths. In addition to viewing this reflected light in combination, as with the eye, one can also use a spectrometer to measure the absorption at any particular wavelength, usually viewed as a plot of intensity (of reflection) against wavelength. Thus, UV and IR absorption, invisible to the eye, can be seen and measured.

Spectroscopy Techniques

Filtered light techniques are a convenient way of distinguishing between materials and suffice in most cases encountered by document examiners. However, there are more sophisticated techniques that measure absolute values of radiation at a specific wavelength, and, as these can also be used for comparison of document materials (more commonly fibers and paints), they need description here.

When wavelengths or colors of absorbed light are referred to, it must be understood that this is a range rather than an individual value. Any substance that absorbs some colors and reflects others does so in a way that can be recorded on a graph. If the absorption at a particular wavelength is, say, 50%, another is 75%, and a third is 100%, these can be plotted as points on a graph (referred to as a "spectrum") on which one axis represents the wavelength and the other the percentage absorption. If the points are connected with a line, which continues for all wavelengths measured, the absorption spectrum of that substance will

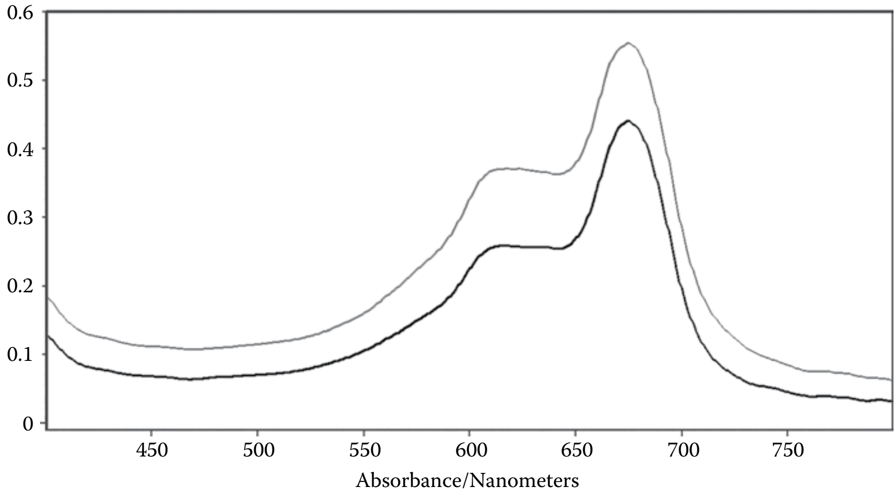

Figure 7.1 A typical visible light absorbance spectrum of a blue ink, measured at two points on the ink line. The horizontal axis shows the wavelength of light, while the vertical scale shows how much of the light at that wavelength is absorbed. This ink absorbs at the red end of the spectrum and reflects blue light; hence, it appears blue. Note the peaks are not sharp, as this is measured at room temperature, and that the shoulders on the peaks are an important feature in distinguishing between inks.

be produced. For an ink, this will typically consist of a curved line with peaks and troughs. An example is shown in Figure 7.1. The peaks will indicate those wavelength ranges that are strongly absorbed, and the troughs those at which the light is reflected, at least in part.

Note that these spectra are sometimes referred to as reflectance spectra, sometimes absorbance. The difference is in the method of collection; the spectrum can be collected by passing light through a sample (transmission) or by reflecting light from a material. The method employed depends on the sample to be analyzed and other factors, but the result is the same in most cases.

In document examination, the most common spectra collected are in the ultraviolet and the visible range of radiation, and this is done using a machine called a microspectrophotometer (MSP). This is a spectrometer that can focus down onto a small area of a solid surface and gather an absorbance spectrum from the reflected light and therefore is ideal for examining an ink line. The technique is nondestructive, and a spectrum takes only a minute or two to gather. If the document can be introduced into the viewing stage, then the analysis causes no damage. Because ink lines microscopically are not uniform, several spectra along the ink line are taken so that any variations can be seen, but as they are quick to acquire, then this is not an issue. The technique will also take spectra of the near infrared (depending on the optics) and therefore covers the range of radiation of most interest in the examination of inks.

The main barrier to use as a routine instrument in examining the materials associated with documents is cost; even a simple teaching instrument is around $40,000 (2017).

Infrared radiation beyond visible light (between 1000 nm and 1 mm) can also be used in materials analysis, most commonly to distinguish between organic-based compounds. Infrared light is absorbed by molecules depending on the way they vibrate (it is a form of vibrational spectroscopy). The instrument used for this is a Fourier transform infrared (FTIR) spectrometer, usually linked to a microscope, although for some applications, an attenuated total reflectance (ATR) attachment is appropriate and would be significantly cheaper. The spectrum produced is a series of peaks and troughs, as before, but usually they are significantly sharper than in the UV-VIS spectra, and can be very characteristic.

From a document examiner's point of view, infrared absorbance is less useful, as paper absorbs infrared light over a broad range of wavelengths and usually dominates absorbance, being composed of cellulose. However, some materials, such as photocopy toner, can be usefully analyzed using this technique.[2,3]

Another form of vibrational spectroscopy is Raman spectroscopy, and some success has been reported in application of this to the examination of a range of materials,[4] including stamp-pad inks.[5] The incident light is usually very specific wavelengths (generated by a laser or other light source), and the absorbance is also very specific. Raman spectrometers can be relatively cheap, and there is no sample preparation as there is no requirement for a viewing stage so documents do not have to be folded or damaged. However, the preferred technique (surface-enhanced Raman spectroscopy [SERS]) can be semidestructive, as a small amount of the surface is removed; the damage is not usually apparent, but permission must be sought before use of the technique.

Luminescence

The way an object appears colored due to the absorbance of certain wavelengths of light by chemicals in the object is described above. There is another effect that can occur as a result of absorbance: when radiation (e.g., light) falling on certain compounds is absorbed and is then re-emitted as radiation at a different wavelength. This is described as "luminescence," a term that embraces both fluorescence and phosphorescence, the former term referring to an immediate effect and the latter to one where the emission of light is delayed for a few milliseconds or longer. The distinction between fluorescence and phosphorescence is not important in the examination of documents, so the term luminescence is used throughout the text. The light being shone on the document is known as the "incident" light and is usually a specific range of wavelengths, while the luminescence generated is known as the emitted light and will be a narrow range of wavelengths, which is determined by the incident light. Varying the incident light will cause different emission effects to come and go.

Ultraviolet radiation, which, as its name suggests, is radiation beyond the violet end of the visible spectrum, has a wavelength between about 200 and 400 nm and will produce luminescence in the visible part of the spectrum. This is the effect often seen in nightclubs, where long-wave UV is shone onto clothing that contains brighteners from washing powder; these change the UV and, in the absence of the red end of the spectrum, appear to make the material glow blue or white.

Luminescence can also be generated in the visible and in the infrared region of the spectrum using blue or green light. Scenes of crime lights such as Foster and Freeman's "Crime-lites" or the "Polilight" can be used as the incident light to generate the luminescence and the supplied filters in these kits used to place in front of the detector. In the case of visible-light luminescence, the emitted light is viewed using the eye as the detector with an appropriate filter contained in a set of goggles placed over it; to view infrared luminescence, an infrared camera and associated filters must be used.

Luminescence is usually of lower energy, a rule known as Stokes Law; thus, if incident UV light is used, one would expect blue or green light to be emitted, while incident blue light will generate yellow or red emitted light; green light will typically stimulate infrared luminescence. The incident light is always of greater intensity (brightness) than the emitted light, so luminescence needs to be viewed in a dark room using good filters. One other form of luminescence is worthy of mention, and that is anti-Stokes luminescence, in which the light emitted is of higher energy than the incident light. This is used in security documents such as passports as an anticounterfeiting measure because it is a rare phenomenon and is difficult to recreate.

Apparatus used for detection of luminescence consist of a light source, an illumination filter to control the incident light, a viewing stage, a detector filter, and a suitable detection device (in cases where luminescence is strong, this could be the eye).

Paper

Most physical documents are based on paper, although, increasingly, bank notes are being made of polymers designed to be hard wearing and for which different analytical techniques will need to be deployed (see Chapter 8). Electronically stored information is playing an increasingly important part in administrative and financial activities, and the use of paper in transactions of all kinds is decreasing rapidly. The examination of digital media has now become a forensic topic in its own right and is not dealt with in this book. That said, the dream of the "paperless office" is quickly dispelled by walking into any working environment, where paper documents are still much in evidence, from printed emails, aides memoire, or sticky-notes, to certificates or wills. How paper is used in the commission of crimes may have changed, but the forensic examination of paper is likely to remain relevant for some considerable time, particularly where documents need to be covertly passed; accessed without electricity; quickly destroyed, such as in terrorism offences; or used to provide proof of identity such as in people trafficking offences. In addition, many require some physical evidence of a transaction, and a signed paper copy of an item, such as a contract or a will, is still the best way of doing this.

Manufacture of Paper

The papermaking process is a well-established technique, and most papers produced for commercial uses such as printing and writing are produced in broadly the same way, described in general terms below. There are a number of specially produced papers such as hand-made papers or those used for specific purposes (e.g., fine art), but as these are not usually the subject of criminal investigations, they are not described here.

Paper is made from pulped fibers that originate from wood, linen or cotton rag, esparto, hemp, or straw. To enable wood fibers to be used—and wood is the most common fiber constituent—it is first treated to break it down to suitably fine pulp, which is done by mechanical or chemical means, a variety of chemicals being used for the process. The fiber pulp is mixed with a large quantity of water and other materials. These include sizing, which is made from gelatin, resins, or similarly effective materials that assist in binding the fibers; minerals such as kaolin to add weight; and dyes and whiteners to achieve the right color. The mixture is then passed over a frame, where it loses much of its water and becomes a wet, matted fiber mass spread evenly over the surface. The frame, which itself gives a characteristic wire pattern to the paper, may incorporate a "dandy roll" or other devices to reduce the fiber content in an area with a recognizable shape. This produces a watermark, which will be more transparent than the rest of the paper.

The fiber mat is finally pressed and heated until it is dried. Some papers are specially coated to produce a surface suitable for the proposed use of the final product. After collection on a large roll, the paper is cut to the required dimensions.

Testing of Paper

The methods of manufacture described above give rise to differences in the end product that can be tested in the laboratory. Because paper is produced in large quantities and there may be little batch-to-batch difference in the composition of paper, most tests are undertaken with the aim of distinguishing between papers. If a difference due to manufacture is found, then the paper can be said to be from a different source; however, if no difference in manufacture can be established, it does not mean that the papers are necessarily from the same source, although that is a possibility.

Invaluable information can be obtained from examination of paper that allows different samples of paper to be compared and dated. In addition, it may be possible for the country of origin of a piece of paper to be discovered. Other techniques can determine what has happened to the paper after its manufacture and thus provide useful guidance in the investigation of crime.

Some of the tests employed can be performed without damage to the specimen being tested, but others require the removal and destruction of a small part of the piece of paper. It is normal to complete the nondestructive testing first, then proceed to the destructive tests until a difference is found.

Nondestructive Tests

Most of the operations in the manufacture of paper provide features that can distinguish one type from another either by direct observation or by more elaborate techniques. Color, shape, size, and thickness of the sheets; the watermark and "laid" marks from the dandy roll and patterns produced by the frame; and the appearance of the surface, which may be evenly colored or mottled, can all be examined by simple observation and measurement, and can be carried out effectively and quickly outside the laboratory. The feel of the paper—how smooth it is or how stiff—can be ascertained by handling, and by the noise it makes when shaken. These apparently crude tests nevertheless have value in the initial comparison of two pieces of paper. They detect difference in makeup with a certainty as great as more sophisticated methods and have the advantage that nothing is damaged or destroyed. In making any such tests, the document examiner should take care not to affect other tests that may be required such as extraction of DNA or treatment for fingerprints.

Visual Comparison

The simplest way of comparing two pieces of paper is to place them side by side under the same lighting conditions. Differences in size, color, laid marks and patterns, printed line quality, and other features quickly become apparent and should be noted. Any differences are usually the result of the two pieces of paper originating from different sources. Overlaying them can also reveal differences in size, but paper is a very hydroscopic material (it absorbs water), so dimensions can vary a little due to this. Allowing them to equilibrate with the surrounding atmosphere for 15 minutes before measurements are taken which will ensure a like-for-like comparison can be made. The next test is to shine light through the document when the translucence, thickness, and any pattern or watermark will be evident. These are all properties resulting from the manufacture of the paper, so any marked difference is usually due to the papers coming from different sources. To quantify these measures, the thickness of the paper can be measured with a handheld screw micrometer (make 10 measurements across the paper, avoiding any watermarks, and take an average); the density can be measured by weighing the sheet of paper and measuring the width and length of the paper (again, taking several measurements). The weight of the paper per square cm can then be determined. Assuming the papers reveal no significant differences, then other techniques as described below are employed.

Absorbance

Paper is usually white, and therefore is expected to reflect all light in the visible region of the spectrum. However, this is not always the case, and success has been reported in discrimination of papers by measurement of their ultraviolet, visible, and infrared absorbance spectra. These techniques can often be performed in situ and are nondestructive. Simply put, a light or radiation source of known intensity is shone onto the document and the resulting reflected light is measured. Chemicals within the paper absorb light at particular wavelengths and therefore the resulting "reflectance" or "absorbance" spectrum shows where incident light has been absorbed by the paper across a spectrum. Usually, a UV-VIS spectrum is obtained using a separate instrument from the infrared spectrum, but the result is a series of peaks that serve to characterize the paper. Papers that appear white can have very different UV and IR spectra, and differences in the spectra indicate different chemical compositions and therefore different origins. The techniques are claimed to have good discriminating power, are cheap and simple to perform, and are usually nondestructive.[6] The test can take two forms—transmission (light shone through the paper) and reflection (light reflected from the surface). Paper is usually homogeneous (the same composition throughout), so there is unlikely to be a difference in the results from these two techniques. When differences are found, the usual inference is that the two pieces of paper are from different sources; however, as with all interpretive issues, a holistic view must be taken of the evidence and care must be taken as to why this difference has occurred. It does not always imply that there has been a deliberate substitution of a page, as batches or reams of paper may come from more than one production run.

Luminescence

Luminescence can also be tested without change to the paper. This phenomenon, of interest in many areas of document examination and other branches of forensic science, depends on the absorption of light and its emission at a different wavelength. The most commonly encountered form of luminescence in the examination of paper is caused by ultraviolet radiation. Different substances luminesce with different wavelengths and intensities. Under the ultraviolet lamp, some papers emit a strong luminescence, while in others it is weak or not present at all. There is a wide variety in the degree of luminescence excited by ultraviolet radiation by different papers, and subtle differences in shade can be easily seen with the eye. A side-by-side comparison will soon reveal differences in luminescence between papers so that issues such as page substitution in a long document are easily detected. In doing this, two important points must be borne in mind; first, UV light, particularly short-wave UV, is associated with skin cancer and eye damage and therefore precautions must be taken to protect eyes and skin. Fortunately, UV is stopped by gloves and glass. The second point is that the luminescence of interest is always of lower intensity than the incident light, so to view the luminescence the incident radiation must be eliminated. In the case of UV, this is done by viewing the luminescence through glass or goggles, thus protecting the eyes at the same time. It is a simple matter to construct a device to shine long-wave UV light onto paper and view the effect in a darkened box.

Destructive Tests

Further tests can be carried out if a small amount of the paper can be removed. This may not be allowed if it is necessary for the document to remain undamaged, but the possible advantage of gaining extra information must be weighed against the value of the document remaining intact. Permission must always be sought from the investigating authority before any sample from the document, however small, is removed, and it is good practice to take a scan or photograph of the area to be sampled beforehand so that the original state of the document can be recorded and demonstrated. Usually, only small areas of paper need to be removed to determine the fiber type, the method of pulping, the dyes present, and the inorganic elements in the paper. Most paper is composed predominantly of cellulose, a derivative of sugar; therefore, the chemicals of interest in paper are present in very small quantities. However, it is the presence of different amounts of these chemicals that can help to determine the source of the paper. Most destructive techniques are aimed at detecting these minor components.

The microscopic appearance of fibers produced from diverse types of wood is significantly different. Consequently, an examination of the "fiber furnish," of the paper may be useful, particularly if the paper to be examined is high-quality paper such as that used in banknotes. Ordinary file paper tends to be manufactured from pine, often with a proportion of recycled fibers, and consequently the examination of the fiber furnish is of less use here. The test involves the breakdown of a portion of paper using water or, on occasion, dilute acid or alkali, into a pulp in which the individual fibers can be examined microscopically. This enables the determination of the original method of pulp preparation (whether mechanical or chemical) to be determined and different varieties of fibers to be identified. These can be materials such as cotton, linen, grasses, straw, and many varieties of fibers from different species of wood. For this test to be useful, the examiner must have access to a library of distinct types of fiber so that the characteristic features of each fiber type are known. It is therefore a highly skilled examination requiring a considerable amount of experience in the identification of wood from cellular material.

Tests can also be performed to determine the chemicals used during manufacture to prepare the pulp from shredded wood, and these are perhaps of more use, as different manufacturers will use different treatments. Other tests determine the elemental composition of the paper or identify the materials used for the surface coating. The scanning electron microscope in its analytical mode (see Chapter 10) can be used for the former, x-ray diffraction for the latter. X-ray diffraction uses x-rays to indicate the crystalline structure of the material, which is characteristic of the compound. Causin et al.[7] have found that all 19 different types of paper examined in one particular study could be distinguished if infrared spectroscopy was used in conjunction with x-ray diffraction.

Over the most recent decade (2007–2017), much has been published on the determination of trace elements in paper using mass spectrometry techniques, usually inductively coupled plasma mass spectrometry (ICP-MS). The technique requires a small quantity of paper to be taken and heated to destruction; the resulting vapor containing ionized atoms is then analyzed to determine the mass of the elements present and therefore the proportion of each of the elements present in the paper. A review of this area has been published by Tanase et al.,[8] in which the amount of the elements Al, Ba, Fe, Mg, Mn, Pb, Sr, and Zn present in ppm quantities in five paper samples from different sources was determined. It was found that the combination of these elements could easily discriminate between samples and, given statistically different proportions, can be taken as a good indication of paper from different sources.

The mass spectrometry technique has been further extended to investigate where in the world a paper comes from using stable-isotope ratio mass spectrometry (IR-MS).[9,10] Elements are determined by the number of protons they have—oxygen always has 8 protons, carbon always 6. However, protons are associated with neutrons in an atomic nucleus, and the number of neutrons can vary. Thus, oxygen has a number of isotopic forms, the most common having a mass of 16 (8 protons, 8 neutrons). A much less common isotope is oxygen-18 (8 protons, 10 neutrons). How much less common is determined by a number of factors (the climate being a key influence), but oxygen-18 is more common in some parts of the world than in others. A similar analysis can be done for carbon, nitrogen, and a number of other common elements. Wood contains lots of carbon and oxygen, bound up in cellulose. If wood that is to go to make paper is chopped down, it then ceases to exchange elements with its environment, so the stable isotope composition of the cellulose is typical of the place where it is grown, not the place it ends up. Thus, paper made of wood from China could be distinguished from paper made of wood from Norway by examining the $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios, and some indication can be given of from where the wood that went into the paper came.

Further techniques can be used on colored paper. Thin-layer chromatography and absorption spectroscopy can be applied to the dyes in the paper. Because these tests are more commonly used on inks, they are considered later.

Comparison of Paper

In forensic science, the tests previously outlined are usually carried out for one purpose: the comparison of one piece of paper with another. The significance of this is to show whether two pieces have a common origin or to indicate whether a possibly counterfeit document is genuine by comparing its paper with that of the genuine article. In the latter, the examination may be assisted by the introduction of small pieces of paper (planchettes) or colored coarse fibers into special security papers as a safeguard.

When two papers are found to be different, they can normally be assigned different origins. However, there may be another reason for this. The source of a piece of paper may be a writing pad or a similar block of different sheets. Although it might be assumed that all the paper in one such pad is the same, this is not always so. Machines that make up blocks of sheets of paper may use multiple reels. Paper from several reels is fed into the machine so that each reel provides parts of the block. The resultant pad will contain paper from each reel in sequence.

When papers are found to be similar, consideration must be given to all the possible reasons for this. Clearly, they could be from the same source and the same batch, but care must be taken not to overestimate the significance of the similarity. A large batch, or a carefully controlled process leading to a very consistent product, means that a considerable quantity of paper would also be similar, allowing for the very real possibility of a chance match between two samples. The examination of paper is therefore more often useful in discriminating between papers that should be similar rather than linking documents together, for which other techniques may be more effective.

Mechanical Fits

A more certain indication of a common source of two pieces of paper is the possibility of a mechanical fit between two or more pieces that were once one piece and have been torn apart. Often the fit is obvious, hardly requiring close examination, but this is not always so. Confusion can arise when two identical sheets are placed together and then torn in one action. One piece of one will nearly fit the other because the general shape of both tears is the same. Erroneous conclusions may also be drawn from a torn edge that appears to have overlapping areas, the apparently extra paper suggesting that the two pieces could not have been one. This occurs because the tear is not always perpendicular through the thickness of the paper but can be at an acute angle, resulting in surfaces that were exactly opposite each other ending on different parts of the divided sheet. In other cases, fibers can be pulled out of the tears and can modify the shape of the resulting edges. These apparent discrepancies can often be explained once the edges are examined under low-power microscopy. Testing the pages by the electrostatic detection method normally used for detecting indented impressions can be helpful in identifying those parts of the torn edges where the paper is thin (see Chapter 9).

In most cases, when two torn edges are fitted together, it can be proved that the pieces did or did not form one piece. The irregular tear pattern normally found could not be deliberately or accidentally reproduced in another specimen. The problem is often made easier when ink lines, folds, or watermarks cross the torn edge. The chance that these would be exactly in the same position in another piece of paper must be very low, and the presence of such artifacts adds another parameter to the accumulation of evidence against a coincidental match.

Sheets of paper designed to be torn apart have perforations that are usually circular but can be elliptical. Other perforations are made with short cuts separated by narrow strips of uncut paper. When the page is torn apart, the breaks that occur in the paper between the holes will not normally be even. Instead, the tongues of paper that remain on either side of the torn perforation will be of varying length, the longer tongues on one side corresponding to shorter ones on the other. It is therefore often possible to show that two parts of a perforated document were at one time joined.

Although book matches can hardly be regarded as documents, they, too, can provide invaluable evidence by the same processes of mechanical fits of paper. Matches left at the scene of a crime have been shown to originate from a book in the possession of a suspect.[11]

Watermarks

Watermarks are produced in the manufacture of paper by a thinning out of the fibers in the required shape and area. When the paper is finally completed, there is little reduction in the dimensional thickness, but there are fewer fibers present. This makes the watermark more translucent than the surrounding area and so creates the familiar effect of the appearance of an image when the paper is held up to the light.

When printing, typewriting, writing, or other marks are made on the paper, the watermark is more difficult to examine. To overcome this problem, it is necessary to employ methods that are sensitive to the difference in mass of paper but do not detect the extraneous information on the paper. If the writing or printing is not visible in infrared, it can be "removed" by photography or electronic means, using light transmitted through the paper and a filter that allows only infrared to pass through the lens. This method is more commonly employed for the comparison of inks or the apparent removal of obliterating inks and is dealt with later in this chapter.

A more elegant method of displaying watermarks so that their details are clear is the use of soft x-rays or beta particles emitted by a radioactive source. This can be achieved by using a sheet of polystyrene containing carbon-14, a radioactive isotope that emits a steady stream of beta particles of low activity. The handling of the material is therefore not hazardous. However, as the radiation is of low power, prolonged exposure to photographic film is needed. To reproduce an image of the watermark, the paper is placed between the sheet of radioactive polystyrene and a piece of light-sensitive photographic paper. After several hours' exposure—it is usually convenient to leave it overnight—the latent image of the watermark will be present on the photographic paper. The radiation has passed through the document attenuated to varying degrees dependent on the mass of the fibers present in the paper. The thinner paper of the watermark allows more radiation to pass than does the rest of the paper, so its shape is reproduced as a photograph. Any printing or writing will have little mass compared with that of the paper in either its thicker or thinner areas and will therefore not be detected.

The watermark can give clear information as to the origin of the paper. From this, the manufacturer can be identified, and, if the design is periodically changed and records of these changes kept, the period in which the paper was made can be discovered. The value of a watermark as a means of security is very high. Although it is possible to imitate one by printing or drawing, the results are rarely convincing. It is particularly difficult to copy the complicated multitone watermarks produced in high-quality security papers.

Dating of Paper

The methods of production of paper have changed over the centuries. New materials have been introduced into the manufacturing process that can then be found in the final product. Antique documents counterfeited with modern paper can be shown not to be authentic because certain materials are present that could not have been used at the purported date of the document.

The Vinland Map, for many years considered to be centuries old, was proved to be a fake by the discovery of titanium dioxide in its paper. This was not used until modern times. Two sets of diaries, claimed to be by Mussolini and Hitler, were shown to be spurious by the discovery of straw fibers and optical brighteners, respectively.[12,13] The inclusion of these components in the paper could not have occurred at the professed date of the writings, as they were introduced considerably later. In the case of fake paintings purporting to be by the 19th-century painter Samuel Palmer, part of the paper used in a picture was shown to be of modern origin.

In most criminal investigations, smaller timescales are of significance. A document may be purported to have been produced a year before the actual date of manufacture. In such cases, only if a change of practice in the manufacture has occurred between the two possible dates of production can any evidence be adduced to show which is the actual date. Changes in practices occur when different types of pulp are used, incorporating different varieties of wood, for instance, and records of these may be kept by the paper mills. Some manufacturers regularly change the dandy roll that produces the watermark because it is in their interest to know when the paper was made if there are complaints about its quality. This is of evidential value if the date of a document is in dispute.

To adduce such evidence, the cooperation of the producer of the paper is required, either by providing information from records or by supplying samples of each different batch when changes are made.

Envelopes

Evidence of the manufacturer may be also provided by the design of envelopes. The size and shape of the envelope, the shape of the flaps, and the type of glue and the pattern it forms all vary between manufacturers, and, in some cases, batches. These can therefore be usefully compared. Some self-seal envelopes bear printed codes that may indicate the date of manufacture, providing another parameter for comparison.

Writing Materials

The materials used to produce a line of writing on paper can reveal information over and above that obtained from whatever can be read. Evidence of considerable value may be supplied to the court from comparison of different inks, detection of ink that has been erased, and, occasionally, determination of the date inks were placed on the document. Techniques for these investigations need to deal with very small amounts of material; the quantity of pencil or ink deposited on paper is far less than its appearance suggests. Although a complete analysis is not possible, many tests, often nondestructive, can be used and are described below. These tests cannot identify the particular instrument used, but the type of ink or other material can be compared. Matching inks indicate that they could have come from the same source, but also from different sources of similar ink. Differences in inks found on one document are usually more significant.

Pencils

Pencils are rarely the subject of forensic investigation, as most documents are completed in ink. In any examination of the mark made by a dry instrument such as a pencil, the amount of substance left on the paper is very small and the variation between different products is not great. Ordinary "lead" pencils are made with graphite mixed with varying amounts of clay or other fillers, a greater proportion of which increases the hardness of the product. Softer leads have a higher percentage of graphite. Colored pencils or crayons are made of wax and colored pigments; different waxes provide a range of hardness to the core of the pencil.

The action of pencils and crayons depends on the friction caused when they are applied to the writing surface. Finely divided residue breaks from the solid core and is embedded in the irregularities of the paper surface. The particles remain on the surface and do not penetrate into the fibers, enabling them to be removed by pressure from a rubber eraser.

Analysis of the small amounts of graphite or wax present on paper requires sensitive techniques. Scanning electron microscopy in its analytical mode can give a quantitative assessment of the elemental composition of the written line. There is a high proportion of inorganic material in the composition of pencils and crayons, and, although the quantity present is small, it is adequate to distinguish between different products.

Erased pencil lines may contain a few traces of graphite that can be detected by increasing the contrast between their absorption of light and that of the paper or whatever substrate on which they occur. Photography using appropriate filters allowing infrared to pass, electronic means of detection, or computer-based image enhancement methods, described in Chapter 10 (on image processing), sometimes assist and allow what was erased to be detected.

Inks

The application of a colored liquid or paste to paper as a vehicle for printed or written information is the basis of the vast majority of documents.

Inks used in printing differ considerably from those employed for writing. These are considered in Chapter 8, where printing techniques are discussed. Toners for electrostatic printers such as photocopiers and laser printers are now of considerable importance, and are also dealt with in Chapter 10.

The present chapter considers the manufacture and examination of the inks used in hand-held writing instruments.

Liquid Inks

Inks were first developed thousands of years ago in China and for centuries were based on carbon particles suspended in an aqueous dilute solution of glue. Today's so-called Indian inks, made in much the same way, produce a jet-black permanent writing line.

Subsequently, iron-tannin inks, mixtures of salts of iron and tannin with some glue, were developed, and they continued in use in a modified form until recent times. The most important modification made in the 19th century was the addition of the dye indigo. This gave a blue color to the line of writing, which after a time turned black as the iron-tannin components oxidized. The mixture was therefore known as blue-black.

The use of dyes was extended first to replace part of the iron-tannin component and then to replace all of it. The advent of the fountain pen, which, unlike earlier quill and iron nib pens, carried its own supply of ink, hastened this development. The employment of dyes increased the range of colors available and enabled washable inks, with entirely water-soluble coloring materials that could easily be removed, to be developed. Other changes, including the addition of alcohols, were made to make the ink dry faster.

Ballpoint Inks

The invention of the rolling ball pen introduced a new concept to placing ink on paper. A ball at the end of a tube picks up ink from the reservoir above it and transfers it to the paper surface. Because the ball rotates as long as the pen is in motion across the paper, the flow of the ink is continuous and applies the required amount to the written line.

Ballpoint inks are not based on an aqueous solvent but on a quick-drying paste. Mixtures of dyes provide the coloring matter, and an important constituent is the resinous material that remains after the solvent has evaporated, which serves to bind the ink to the paper. The convenience of the ballpoint pen has given it pride of place among all other forms of writing instrument. Most handwritten documents are now completed with one, and it appears that it will remain the most popular form of pen for years to come.

Fiber-Tipped, Rollerball, and Gel Pens

After the development of the ballpoint pen, felt-tipped markers were produced. These depend on a compressed fiber stylus transferring ink from the reservoir to the paper by capillary action through the gaps between the fibers. In felt-tipped markers, the fibers are less densely packed, and the writing tip is wider. In a fiber pen, a more compressed fiber bundle can be made sufficiently narrow to produce a line similar to that of a fountain pen. The inks used in these instruments are water based, with alcohols and other solvents added to induce quick drying, and use dyes like those of other aqueous inks for color.

A further development in pen design produced rollerball pens, employing the same principle of ink delivery as that of the ballpoint pen but using an aqueous-based ink. The inks used in these pens, like those in felt-tipped pens, depend on water-soluble dyes for their color.

A later development is the introduction of gel pens. Although like a rollerball pen in action, they use a more viscous ink. These inks were originally colored with pigments (insoluble colored chemicals) rather than dyes, which made them difficult to analyze, but later inks have used dyes. These enable a greater range of colored inks to be made, but black and blue inks are most common and are increasingly sold.

The Examination of Inks

It is sometimes necessary to show whether a particular pen was used to write certain material. More often, it is necessary to show whether two inks on one document are the same. The addition of extra writing can greatly change the meaning of the wording or the amount of money. Additions range from long passages to a single digit as simple as a figure *1*, which can increase the apparent value of a document many times.

During the manufacture and development of pens and inks, tests are performed with the aim of improvement of quality, reduction of cost, and other factors of importance to the maker. Ample quantities are available, and complications, such as the presence of paper, can be obviated or controlled. In contrast, the examination by the forensic document examiner is made on a small amount of ink already dried on the paper. Any technique that requires an amount of ink to be removed, however small, will disrupt the integrity of the document, and permission to damage a document must be sought from the appropriate authority. It may be that the document is valuable, and removal will reduce that value, it may be that removal will prevent others from re-examining the same document, or it may be the owner simply does not want it damaged. There may be extra problems if other evidence types such as DNA or fingerprints are needed, as sampling the ink may compromise these other examinations. The first techniques employed, therefore, are those designed to obtain as much information as possible from the ink by visual or other nondestructive means. After this, those requiring samples to be taken from the paper are used. The methods are described in this order.

There are several papers that review the analysis of inks, and the American Society for Testing and Materials (ASTM) has produced standard methods for the examination and comparison of inks, (ASTM 1789-04 and 142-05). Improvements to standardize these methods have been made by Neumann and Margot.[14]

Visual Examination

The eye is in itself a powerful scientific instrument, capable of discovering much information from an examination of ink on paper. With the aid of a microscope, using low power, giving a magnification of up to 100×, the appearance of a line written on paper may give invaluable information. The appearance of a ballpoint ink line under a magnification of around 20–50× provides clear evidence of its origin. As ballpoint inks are only partly absorbed into the paper, they have a characteristic glossy appearance, and their pasty texture is unmistakable. In many cases, striations caused by imperfect or dirty ball housings are apparent, and there is a tendency, just after the pen has turned a corner, for an extra amount of ink to be deposited in the line. The extra pressure required when writing with a ballpoint pen will frequently produce indentations in the paper.

In contrast, a water-based or "wet" ink will color the paper by being absorbed into it, in effect by dyeing it in a narrow line. The ink itself will be visible not as a layer of added material but rather as a colored area of an evenly textured surface. Whether the line is made with a modern fountain pen, with a tipped nib giving an even width, or with a fiber-tipped or rollerball pen will not normally be apparent from the appearance, even under magnification. The depth of indentation will be small or nonexistent, but a faulty instrument may leave some indication; the housing of a rollerball pen when it is held at an oblique angle to the paper may leave an indentation parallel to the line. However, the use of a wide pen nib will be shown by the variable width of the line.

Other non-ink writing instruments will leave characteristic traces. Pencils and crayons smear solid deposits on the paper, and these can be seen as such under the microscope. The shiny appearance of graphite and the waxy look of crayon on the surface of the paper are unlikely to be confused with other materials. Carbon paper impressions can sometimes cause problems, but their most distinctive feature is the gradual shading of the edges of the line. This, produced by the lower pressure of the depressed paper away from the center of the writing instrument, contrasts with the sharp cutoff of the edges of writing made directly on the paper.

Apart from the distinction between different types of ink, variations can be detected between inks of the same type. The texture may vary considerably, especially within ballpoint inks, and the width of the line will depend on the size of the ball or stylus used. The presence of striations in a ballpoint line can also distinguish between different pens. Erasable ballpoint inks have a characteristic appearance under magnification of about 100×. They can be distinguished from normal ballpoint inks because they use a thermochromic ink that has a rubber-based vehicle that appears as fine strings of ink under a microscope.

As well as differences in appearance, color is very significant in the comparison of inks. Shades and depth of color vary considerably, and under the microscope, differences between inks can be detected visually. Care must be taken because lines made at one time by a single instrument can also vary in intensity.

The Examination of Inks Using Filtered Light Techniques—Absorbance

Inks are made up of mixtures of dyes that, in combination, absorb the appropriate wavelengths to give the required color. The dyes used are not common to all inks, so there is considerable variation both in the color and the absorption spectrum of the combinations. Sources of reflected light with two different absorption spectra can appear identical because the eye mixes the combination of wavelengths reflected. For instance, green can be reflected by either a green dye or a mixture of blue and yellow dyes. Therefore, because two very similar colors can be produced with different dyes with different absorption spectra, the fact that two inks look the same is not an indication that they are. Methods have therefore been devised to detect these differences.

The simplest method is to use light of a color other than white and observe both inks under it. This will detect differences if those parts of the colored incident light reflected from the inks appear different to the eye. This separation does not occur very frequently.

Another method of detecting differences in absorbance is to use a dichroic filter. This is a combination of two colored-glass or gelatin filters bound together so that light passing through one must pass through the other as well. A useful combination is that using a red and green filter. Light passing through both filters will be partly absorbed, dependent on the light reflected from the ink and absorption spectrum of the combination of the two filters. The light thus transmitted will consist of small "windows" at certain wavelengths. If a small quantity of a particular color is reflected and is of the same wavelength as a window, that color will be visible. A difference in absorption at that wavelength in two inks that appear similar will therefore be detected.

The most common methods for the examination of inks are filtered light examinations (FLEs), which can be used to view both the absorbance of light and the re-emission as luminescence. These methods are described in more detail above under the headings "Absorbance" and "Luminescence." A more sophisticated method of determining the absorption curve is to measure it with special equipment. The apparatus used for this is the microspectrophotometer (MSP),[15,16] which produces a reflectance spectrum of a microscopic section of ink examined, essentially quantifying the color of the ink, as explained earlier in the chapter (see "Light"). The latest machines allow the ink to be examined in situ alongside more standard absorbance and luminescence examinations.

While visible light is absorbed by different inks of a similar color in ways that are only slightly different, there can be a very big contrast between certain inks in their infrared absorption (see Figure 7.2). Whether an ink absorbs infrared also depends on the chromophores in the molecules of the dyes present. Blue inks are all likely to absorb red light, but some will absorb a range of frequencies that extends well into the infrared range, while in others, the absorption will be confined to the visible or near infrared. This variation will not affect the color of the ink because the eye will not detect the presence or absence of infrared radiation.

Therefore, the absorption spectrum of an ink measured using an MSP may show that it continues to absorb radiation from the red through to the infrared, or the absorption may fall to nothing near the end of the red end of the spectrum. In the first case, the ink, when radiated with infrared, will absorb it, but in the second case, it will not. In the latter event, the radiation will pass through it or be reflected from it as if it were invisible or transparent. This is exploited using a purpose-built filtered light apparatus such as the VSC made by Foster and Freeman Ltd. (described in Chapter 10), which incorporates light sources, filters, a visual display unit, lenses, and IR-sensitive charge coupled device (CCD) cameras. This enables a wide range of examinations to be carried out in ideal and well-controlled conditions. Further modifications to the VSC and similar apparatuses developed by other manufacturers, such as the Docucenter made by Projectina AG of CH9435 Heerbrugg, Switzerland, incorporated improved light sources, detection and image enhancement techniques, and printers that enable an immediate record to be made of what appears on the screen of the monitor.

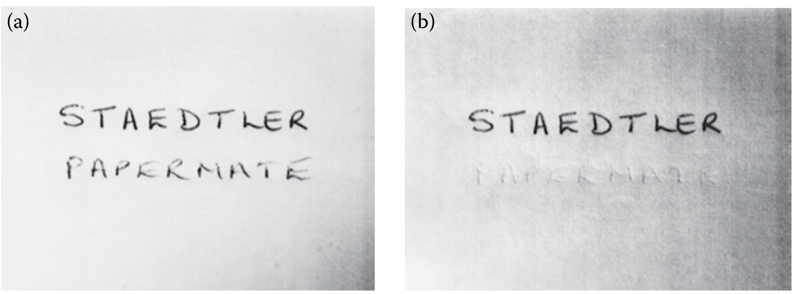

Figure 7.2 Two black inks of different manufacture photographed in (a) normal light and (b) infrared radiation, showing the difference of absorption in the infrared region.

Detection of Infrared Radiation

Photography was the first method employed to detect infrared radiation. Suitable filters that allow only the appropriate wavelengths of radiation to pass are placed over the lens, and a film sensitive to infrared is used. Good-quality photographs can be obtained by this method. While photographic paper has been replaced by CCD cameras sensitive to a range of light from 380–1000 nm, the basic principle is the same. The document to be examined is placed on a viewing stage and illuminated with a white light containing a complete spectrum of radiation, from 400 to 1000 nm. A detection filter is introduced between the reflected light and the camera, and the resulting captured digital image can be viewed on a screen. These detection filters are known as "long-pass" filters because they allow only radiation of a wavelength longer than a specific wavelength to pass (e.g., a long-pass filter of 730 nm will block light from the blue end of the spectrum, but allow wavelengths from 730 nm to well into the IR spectrum to pass). By varying the long-pass detection filter, different sections of the reflectance spectrum can be viewed and differences in the reflectance properties can be determined.

Infrared Absorption

The devices described above provide a sensitive method of detecting differences between inks, for example, when it is suspected that one entry has been added to or altered using a second ink. The essential principles to bear in mind when interpreting the results are that:

- The illumination source must contain light of even intensity in the range 400 to 1000 nm (it therefore appears white).
- When looking at the resulting reflected light through a long-pass filter, the examiner sees all the light reflected that is longer than that wavelength (it is additive), not just the light at that wavelength.
- The technique is always comparing the background reflectance with the reflectance of the target ink.

The consequence of the last point is that one cannot compare inks on papers or backgrounds with different reflectance properties, as this will alter the relative reflectance (i.e., the same ink written on blue paper may appear to have different absorbance properties when written on white paper—this is a common mistake made by people unfamiliar with the principles of this type of equipment).

Most of this equipment is operated by placing long-pass filters of sequentially increasing value from around 600 to 1000 nm in front of the detection device. There is usually around a 30-nm gap between each filter, although this can vary according to manufacturer. Some inks contain components that absorb into the far infrared and so are detectable throughout the range; these will appear dark against a white (reflective) background. Others contain dyes that absorb only in the visible part of the spectrum and therefore become invisible when viewed in the near infrared, above 730 nm. This is because they are reflecting light to the same extent that the background is reflecting light. Others absorb further into the infrared region, gradually or suddenly fading as longer-wavelength long-pass filters are introduced, becoming "invisible" at above 800 nm. It is therefore possible to test the similarity of inks by determining at what wavelength they cease to absorb infrared radiation and become invisible. In some cases, it is possible to discover a clear difference between two inks on a document, one disappearing at a certain wavelength while the other remains visible. The difference is noted by recording the wavelength of the filter at which total reflectance is seen. When comparing two ink lines by this method, a difference by two or more filters is usually due to a difference in the ink composition. Care must be taken to allow for the fact that a thicker, more intense line will show up more clearly than a weaker one of the same ink in the same conditions, particularly if the difference is by one filter. The difference can be mistaken for that between two inks, but is in fact one line absorbing more strongly than the other. For this reason, it is best to select several areas of the ink in question for inspection to study the intra-ink variation.

A second circumstance where varying absorbencies of different inks can be used is in cases where an entry has been heavily obliterated with another ink. If the added ink is invisible in infrared and the original entry is in an ink that absorbs infrared, the original will be detected as if the obliteration were not there once the correct detection filter has been introduced. (Figure 7.3).

If the reverse is the case and it is the original ink that disappears, the alteration can still be determined. In this instance, the final image with the original ink faded is captured and reversed digitally so that black becomes white and vice versa. This negative image is then superimposed onto the

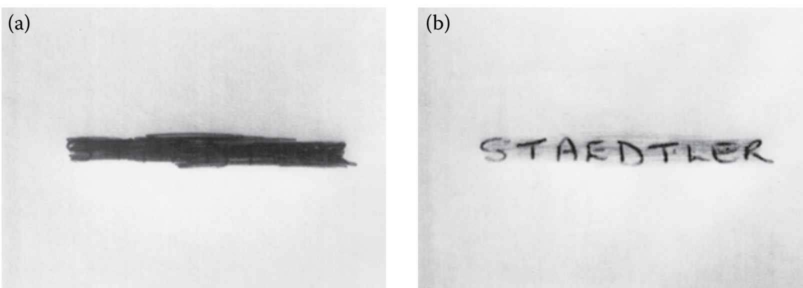

Figure 7.3 (a) An obliteration of one black ink with another, photographed in normal light. (b) The same, photographed using infrared radiation.

original image taken under normal lighting (i.e., both inks absorbing). By adjusting the intensity of one image over the other, the parts that are in both images will disappear, leaving the parts of the original entry as white images. While this image processing requires some interpretation, as not all the original entry will be visible, it can help to determine what has happened.

Apart from comparison of two inks, the technique of examining documents in infrared conditions has other uses. Pencil lead, which is made largely of graphite, absorbs throughout the infrared range as well as in the visible spectrum. If a simulated signature is made by writing over pencil lines in an ink that is transparent in any part of infrared radiation, the graphite can easily be detected. Even when the pencil line is removed by an eraser, traces may remain, and, without the overwriting ink, can be clearly identified.

Ultraviolet and Visible Light Luminescence

Illumination with ultraviolet light can produce luminescence in the UV and visible regions of the spectrum. Luminescence produced by paper varies greatly, and, as has been discussed earlier in this chapter, can be used as a means for testing whether two or more pieces are similar or different. Other materials, such as glues, adhesive tapes, and sealing waxes, can also be distinguished by their luminescence. The application of solvents or chemicals to paper can cause the luminescence to change, so that when they have dried and apparently have left no trace, an area of different luminescence will be found when the document is examined under ultraviolet radiation.

Luminescence in the longer wavelength range of the ultraviolet region can be produced by ultraviolet radiation of shorter wavelength, and some differences between inks in this respect have been reported.[17] As the luminescence is not in the visible region and cannot be observed, special equipment is needed to detect it. This, in addition to the likelihood that differences that can be detected by these means can also be found by other techniques, has resulted in little use being made of this phenomenon.

Inks affected by chemical action rendering them invisible may leave traces in the paper. These inks, if they are not diffused by the solution, may be detected by their luminescence emitted when ultraviolet radiation falls on them; ultraviolet examination may therefore reveal the writing that has been erased. This method was more useful in the past, as the older formulations of ink were more likely to leave evidence enabling their detection by this means. Infrared luminescence, described below, is more successful for the dye-based inks of today. However, a quick examination under a UV lamp in a dark room and wearing simple clear-glass goggles (to protect the eye and eliminate near-UV) can reveal something about the history of the document and should not be neglected.

Some modern inks are intended to be visible only in ultraviolet radiation. These are special preparations used to mark items to enable their identification if they are recovered after a theft. There are also those inks used to write signatures on various documents that for security reasons are visible only when viewed under ultraviolet. It is rare for any of these invisible inks to be involved in any laboratory examination.

Infrared Luminescence

Infrared luminescence, together with luminescence in the red region of the spectrum, is emitted by inks, papers, and other material on a document, such as the remains of erased inks. The effect is described in detail earlier in the chapter.

The important principles of this technique are:

- It must be carried out under darkened conditions, preferably a dark room.
- Varying the illumination filter will change the luminescence detected.
- Luminescence is much lower intensity than reflected light.

A consequence of the last point is that the efficiency of the excitation of luminescence is not great, so a high intensity is required to produce a detectable result. Also, the detector filter must be a long-pass filter and must stop all the illuminating light from passing through. Thus, if the illumination filter is 354–469 nm, the detector filter must be a long-pass filter of at least 470 nm.

In normal operation for inks, an illumination filter of 600 nm is selected. With this illumination, the document will reflect green-blue light as well as emitting infrared or red luminescence from those areas that will generate it. A further filter is therefore needed to eliminate the exciting light from the means of detecting the luminescence. The luminescence can be detected by photography or a suitable CCD, but normally specially designed apparatus such as the VSC (see Chapter 10) is used. Different luminescences from different inks can be detected using a range of filters and the resulting images printed.

In the same way that luminescence excited by ultraviolet radiation is of a longer wavelength and normally occurs in the visible range, so visible light excites luminescence only in the longer wavelength regions in the visible spectrum or in the infrared region. With infrared luminescence, there is also the problem that, in contrast to that excited by ultraviolet radiation, little or nothing can be seen by direct vision. It is therefore necessary to use photographic or, more usually, electronic means for the detection of luminescence. Suitable sources for the excitation of infrared luminescence are provided by intense tungsten filament, quartz iodine, or xenon arc lamps, with appropriate glass or gelatin filters. Alternatively, suitable light emitting diode (LED) light sources can be used. These allow the green-blue exciting radiation to pass but prevent infrared or red light from the source from falling onto the document thus illuminated. Further protection from adventitious intense light must also be provided, as this, too, can swamp the weak luminescence.

An extension of the use of green-blue light to excite luminescence is to use the light from a laser. The advantage of this is that the light is intense and monochromatic, so the incident light is conveniently removed from view by wearing goggles. Any luminescence generated is also more intense and very specific to the incident light, which means that visible luminescence much closer in wavelength to the exciting light can be detected. Observation of visible luminescence is made through filters that are specially made to cut out the laser wavelengths. These are normally incorporated into goggles, which are in any case necessary to protect the eyes. Alternatively, the luminescence can be recorded either by photoelectric or photographic methods, which are the only ways of detecting radiation emitted in the infrared range.

Comparison of Inks Using Infrared Luminescence

Infrared luminescence has proven to be of immense value in the examination of documents, far exceeding in importance the effects of ultraviolet radiation.

First, although many inks luminesce in the infrared region, some do not (see Figure 7.4). Second, there is a further variation between different inks both in the wavelength range at which the luminescence appears and in its intensity. Because examination of inks normally takes place on paper that itself may produce luminescence, that of an ink will appear different on different papers. If the luminescence of the paper is stronger than that of the ink, the latter will appear not to fluoresce. In most cases, however, inks are examined for comparison of two writings on one document. The typical case is where an addition or alteration may have been made at a later date.

If it is necessary to compare ink from a pen or a bottle with ink on a document, a mark can be made with the ink on the same page. Comparison under infrared luminescence conditions can then be made.

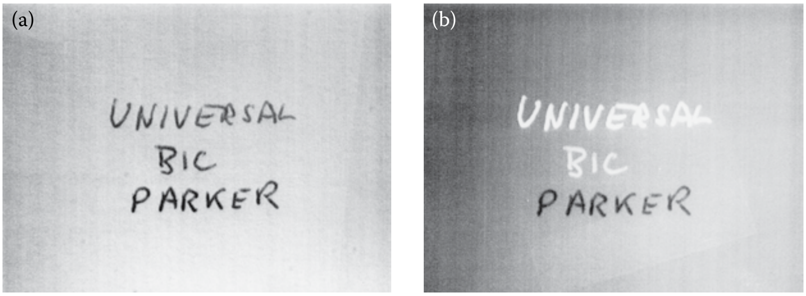

Figure 7.4 Three blue inks of different manufacture photographed in (a) normal light and (b) conditions suitable for the excitation and detection of infrared luminescence.

The distinction between different inks was discussed earlier when absorption or reflection of infrared radiation was considered. Observation of the questioned entries on a document in conditions that will detect infrared luminescence will often distinguish between two inks, whether they can be separated by infrared reflection or not, but emphasis must be placed on ensuring a like-for-like comparison when interpreting the results.

The green light generated is shone onto the document and viewed through a detector filter placed between the document and the CCD infrared camera. The detector filter is gradually increased in wavelength from 630 up to 1000 nm in the same way as is done for the detection of absorbance. This time, the viewer is only seeing light changed in wavelength; there is no reflected light. Inks can appear bright against a dull background, or vice versa. Just as before, the viewer is seeing all the light emitted above a certain wavelength and is comparing the luminescence of the ink with the luminescence of the background. The point at which the luminescence begins or ceases is recorded by making a note of the value of the illuminating (short-pass) filter and the detector (long-pass) filter. Similarities in luminescent properties of an ink under the same conditions and viewed against the same background are a positive similarity; differences are a good indication of a different ink. In some cases, differences in luminescence can be detected only by a change of wavelength of the exciting radiation (the illuminating filter).

Care must be taken in interpreting this evidence. A slight difference between two inks could be caused by different quantities of ink on the surface. Also, sometimes quenching can occur whereby expected luminescence is not visible, as it is immediately reabsorbed by the background. An ink crossing from one type of background to another (perhaps on a printed document) can appear luminescent on the unprinted surface but not on the printed surface of the same document. Luminescence is quenched by compounds that absorb its wavelength; this can cause complications. An ink absorbing radiation at, say, 750 nm may also contain a component that emits luminescence at this wavelength. This will then not be detectable, because it is self-absorbed, but if the component spreads away from the quenching constituent, its luminescence will be observable. This can occur when the surface is moistened, the water or other solvent removing the fluorescing component from the body of the ink. If this happens in only a part of the document, the luminescence of that part may erroneously be taken to indicate a different ink. Generally, however, infrared luminescence can complement infrared reflectance in distinguishing two different inks in one document.

The complications caused by relative luminescence are increased because the wavelengths at which they occur may be different. By changing the filters in front of the detector, different effects are observed. An ink will appear brighter than its background at one wavelength and less so at another. The effect of absorption of light at a particular wavelength will also reduce the luminescence of an ink, so that that from the paper will appear greater.

Comparison of inks on the same background using the luminescence of ink depends, therefore, on a system that will enable its detection to be made at a number of different wavelengths, from about 650 to 900 nm.

Erasures

While the use of ultraviolet, referred to earlier, has been of decreasing value in the detection of erased writings, modern inks have proven to be more productive of luminescence excited by visible light. Inks that have been made invisible by the removal of the colored components can be detected by the luminescence of whatever remains on or just below the surface. Erasures are made by three methods: the mechanical removal of the ink by scraping the surface until all the visible ink has been removed, the treatment by bleaching solutions that convert the dye into colorless compounds, and the removal of the soluble dyestuffs by suitable solvents. In all these processes, it is possible that traces will remain that will luminesce when illuminated with visible light.

As previously noted, the luminescence will be weak, so sensitive methods of detection are required. Again, the observation will be affected by the luminescence of the paper, which can in some cases be greater than that of the traces of ink residues. It is therefore necessary to observe the erased area in all possible variations of wavelength. Sometimes, too, the exciting light can be varied. The laser is a particularly useful tool for erasures on documents because it provides high-intensity illumination and because luminescence that is close in color to the exciting light can be detected.

It is not always clear what is being observed. When an ink dries on the paper, certain components may penetrate more deeply into the surface than others. If these are not visible, there will be no reason to remove them when mechanical erasure is being made. If they are not soluble, they will not be taken out when the colored components are dissolved away. If the dyes are converted to other compounds, these may luminesce, even if the original ink did not. The reasons for what has occurred are not as important as the fact that the ink or its remnants can be detected and the erased entry identified.

Infrared luminescence can be of value in detecting erasures of other materials such as typewriter/printer ribbons and stamp and pad inks.

In some cases, it is not possible by this method to find out what has been erased; not every erased ink will produce a luminescent trace. Usually, however, evidence will be found to show that something has happened to the paper surface, that some action has taken place. A ring of luminescence, rather like a tide mark, different from that of the rest of the surface, is an indication that a liquid has been applied to the paper. This in itself can be of importance to show that the present entry is not necessarily the original one.

When written entries are altered by removing parts of an ink line, it may be possible by simple observation to determine what was originally present. Although the more sophisticated methods described above are available, they do not always produce satisfactory results. With or without the aid of a microscope, traces of ink or pencil may be detected and visually pieced together to identify an erased entry, often by using several lighting techniques in combination. Oblique lighting, exploiting any indentations of remaining writing that may be present, and different-colored filters, to ensure the greatest contrast between the ink and the paper, will be of assistance. It is not always the brightest of illumination that is most effective; sometimes the best results are obtained in low light levels. In addition, it is important to inspect the whole document with a variety of methods; for instance, the reverse of any erasure should be inspected as well as sheets in contact with the area and underlying sheets of paper for traces of ink that have transferred.

Erasures commonly require more than one technique for successful recovery of all the information. This can be conveniently done through the generation of various electronic images using the different techniques, which can then be manipulated and superimposed on to each other to form an impression of the original document. In doing this, the examiner must be able to show how all the original images were obtained and how they have been combined. In short, the process must be auditable for presentation in court later. It is also vital to include a scale in each of the images so that the right magnification and orientation of the image can be maintained. To a lesser extent, this kind of reconstruction may be useful in the decipherment of alterations and obliterations; the same rules apply.

Traces of pencil from an erased entry can be enhanced by photography using high-contrast conditions, or electronic means of detecting infrared, such as that described previously, can also be employed to make the traces more visible.

Indirect methods can also be of assistance. Indented impressions on the piece of paper below the erased writing or "reverse impressions" on the back of the page detected electrostatically (see Chapter 9) have been of value. In one case, these, combined with enhanced visibility of traces of a pencil line, were used to identify very significant erased pencil writings.

Obliterations

Obliterations of an entry are sometimes made in a different ink. As has been mentioned earlier, it may be possible to decipher the original by examination under infrared radiation if the overlying ink does not absorb infrared radiation and the covered entry does. If both react in the same way in these conditions, the technique will be of no value. However, if one luminesces, the problem may be solved. A luminescent ink under a nonluminescent one will

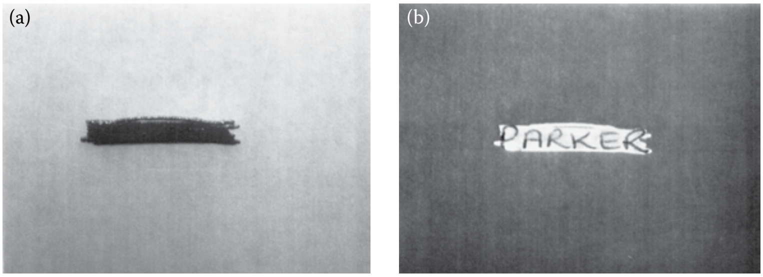

Figure 7.5 (a) An obliteration of one blue ink with another, photographed in normal light. (b) The same, photographed in conditions suitable for the detection of infrared luminescence. Although the obliterating ink luminesces strongly, the nonluminescing ink absorbs the luminescence.

be visible, provided the obliterating ink does not absorb the luminescence. On the other hand, if the covering ink is luminescent and the obliterated entry absorbs that luminescence, a dark area corresponding to the shape of the latter will be apparent. The luminescence of the covering ink is quenched by the ink of the original writing below it. Sometimes careful control of the lighting and filtration conditions is required (see Figure 7.5).

When an ink has been heavily written over and the techniques using infrared reflectance or absorption described above are not effective, microscopic examination may prove able to solve the problem. If the obliterating ink is of a different color, the choice of filters to render it as invisible as possible can help. An image taken in conditions that give the greatest contrast for the original ink and its background and the lowest for the obliterating ink will sometimes "remove" much of the obliteration. This can sometimes be done using image manipulating software such as Adobe Photoshop™. In such cases, it is important that any manipulation of the image be done on a copy of the original file and not on the original. This ensures that any changes made to the image can be seen.

In some of these cases, it is possible to identify an obliterated entry because there is a sufficient amount of it uncovered to provide the evidence. If an enlarged image is made under the most favorable conditions and then those lines that are clearly in the obliterating ink are "whitened out," the portions of the original entry that remain, even though they are not complete, are more easily read without the distraction of the overwriting.

Obliterations are also made with correction fluids; these are dealt with in Chapter 6.

Other Luminescence Effects

Luminescence has been observed under laser radiation when a component of an ink has been offset from another page with which it has been in contact. It is not clear what part of the ink has been "printed" onto the adjacent page, but the effect is detectable only under laser light and may be transferred from one source to another. Transparent plastic tends to absorb traces of ink or paint from credit cards, so wallets specially designed for these will often show an impression of the details from the cards that they once contained.

A case has been reported where a vehicle index number was written on a hand and later washed off. Traces of the number could be detected by luminescence under laser light many hours later. Prints made with fingers contaminated with luminescent materials can also be detected.[18]

Destructive Techniques

So far, the methods described to examine inks have not included those where there is need for any damage to be made to the document. They have the advantage that the ink, erased or not, the paper, and any other marks on it are not affected in any way. Other tests may be performed that provide additional information but that require portions of ink or other materials to be removed. Earlier, mention was made of methods used to test paper that require the taking of a sample on which to operate. Similarly, the components of writing inks, whether they are from ballpoint pens, fountain pens, or fiber-tipped pens and markers, can be further examined by chemical techniques that cannot be performed except away from the paper.

There is no point in causing damage to a document if any information so obtained would not carry the case any further. If, for example, two inks have been shown to be different by nondestructive methods, there is no need to proceed with further work. If it is important to discover whether two inks are similar and they cannot be distinguished by visual and other nondestructive means, further work is necessary. Before any damage is made to the document, it is important to make a permanent record of the entries to be tested. A high-quality image, preferably stored without compression, is suitable for this. It is also important to obtain permission from the document owner or the investigator before any material is removed from the document so that any other tests, such as fingerprints or DNA can be considered as a precursor or alternative to destructive tests.

Sampling

The amount of sample required for comparison of inks is relatively small and should be done with extreme care so as not to affect any other tests that are needed on the document and to ensure the integrity of the document is preserved. Most of the tests described can be done on about 1 cm (or less) of an ink line. To sample a document, a straight part of the ink line is chosen, if possible. Fine cuts are made using a scalpel, viewed under a microscope, down either side of an ink line, ensuring that the scalpel point does not penetrate the lower surface of the paper. Then, two cuts across the ink line are made, forming a small rectangular segment of ink that will be removed. One corner of the segment is then levered up using the scalpel blade, gradually and carefully pulling the top layer of paper, containing the ink, away from the lower layer of paper. Eventually the segment will come free of the substrate and can be removed from the surface using tweezers and carefully placed in a small glass tube or vial for subsequent analysis and to prevent loss. The net effect of this technique is that the sample contains less background paper, sampling does not include the other side of the paper (which may contain other entries in other inks), and the place from which the sample has been taken is clear. In any comparative examination of inks, the background material (usually paper) will be extracted as well, so a sample of this must be obtained and analyzed alongside the ink samples themselves. The areas that have been sampled should be marked on the photocopy of the original document. The methods used for the further examination of inks, usually for comparison purposes, can exploit the variation found either in the coloring materials or other components of the ink. Dyestuffs provide the best opportunity of discrimination between two different inks. The most sensitive method to detect the components that are dried on the paper is to exploit their strong color and to use methods that depend on this.

Chemical Tests

In certain cases, it is possible to distinguish between two inks by their solubility. When a drop of a solvent is applied to a line of writing, the dyes may "bleed" into the surrounding paper. Most ballpoint inks are based on similar vehicles that bind them to the paper surface and react in the same ways to whatever solvent is applied. Other inks may or may not be soluble in water and so could be quickly distinguished from each other by the application of a simple test, saving time and avoiding further change to the document. Solubility tests are best done in a glass vial on a sample removed from the original document, rather than on the original document itself.

When an iron-based ink, now rarely found, has been made invisible by chemical agents, the colored compounds having been converted to colorless ones, it is possible to perform a further chemical reaction to create another colored iron salt and render the ink visible again. This can be done in two ways. In the first, the document is exposed to fumes of thiocyanic acid prepared by mixing potassium thiocyanate and dilute sulfuric acid. Any iron salts in the paper are converted to the red-brown ferric thiocyanate. In the second method, a dilute solution of potassium ferrocyanide can be applied to the surface, and the iron containing ink traces will turn dark blue as they combine to form ferric ferrocyanide.

Chromatography

The principle of chromatography is that individual components of a mixture are separated and therefore can be identified or compared with those of other mixtures to establish whether they are similar. Two methods are employed in the examination of inks: thin-layer chromatography (TLC) and high-performance liquid chromatography. The former is in more general use. The principle depends on a small amount of the material to be analyzed being introduced onto a "stationary phase," which will absorb it. The "moving phase," a fluid (referred to subsequently as the "eluent"), is then passed through the stationary phase and carries the material with it. The speed of travel of the material through the stationary phase is dependent on its composition and its relative affinity for the stationary or liquid phase. Different compounds will travel at different rates, so the method is ideal for separating mixtures and identifying their components by the distance of travel. Roux et al.[15] compared the discriminating power of three techniques and found thin-layer chromatography to be the best, followed by filtered light techniques, then microspectrophotometry. However, as TLC is destructive, it is often employed last. When the techniques were applied sequentially, 99% of inks could be distinguished.

Thin-Layer Chromatography

A coating of silica gel spread evenly on a background of plastic or aluminum constitutes the stationary phase in thin-layer chromatography. Assorted sizes and grades of plate—the name given to the layer and its support—can be purchased depending on preference, but they are usually rectangular, with one of the shorter sides forming the base of the plate. The materials being analyzed are introduced to the plate by the addition of drops of a solution of them to a small area near the bottom edge. This is known as "spotting" the material. The plate is then placed into a suitable solvent, the eluent, so that this rises by capillary action through the thin layer of silica. As it does, it takes with it the different components of the mixture that, because they have a different affinity for the solid and liquid phases, rise at different rates and are separated. When the eluent has nearly reached the top of the plate, the plate is removed and the components of the material being analyzed remain in the positions they have reached.

In the analysis of an ink, there are many different systems described in the literature, but all follow roughly the same principles described above and will not be detailed here. In general terms, the method is as follows:

First, the plate is carefully prepared before the samples are introduced by drawing a pencil line about 1 cm above the lower edge of the plate; this is where the samples will be placed, distributed evenly across the width of the plate. Care should be taken not to disturb the silica surface, and some practitioners leave a gap where the sample is to be placed. (Silica dust is harmful through inhalation.) A gap of around 0.5 cm should be left at the sides of the plate to avoid edge effects (eluent running unevenly up the side of the plate) and between each spot. A portion of the ink line is then removed as described above and placed in a small glass vial (see "Sampling") to which a few drops of a suitable solvent is added. The most effective solvent for inks is a 50/50 pyridine/water mixture. While pyridine is a hazardous chemical that must be used in an extraction hood, the method uses only small quantities and is much more effective in extracting the dyes used in inks than other systems. If no extraction hood is available, a 50/50 mixture of methanol and water can be used. Once the dyes are in solution (usually 5 minutes agitation in the solvent is enough), the solutions of inks that are to be compared are spotted along the line near the bottom edge of the TLC plate using a fine glass capillary tube, one for each sample to be analyzed. The process of spotting is vital to the success of the technique. To do this, the capillary tube is placed into the solution to fill it. The tube is then gently placed in contact with the silica plate at the position where the spot is to be created (on the pencil line). A small amount of the solution is drawn from the tube onto the plate through capillary action. As soon as this is seen, the tube is removed and the resulting spot is allowed to dry; the process is repeated by placing the capillary tube back into the center of the spot, thus building up the concentration of the sample. The final spot should be less than 2 mm in diameter and visibly colored. It is good practice to run the ink samples alongside a control—an ink of known composition—and also against the paper background sample, extracted and spotted using the same method as the ink samples. In this way, any contamination or inconsistency in the method can be detected and any dyes coming from the paper rather than the ink can be identified. It also means that multiple plates can be compared, provided they are run under the same conditions. The eluent is typically a mixture of solvents such as water, ethanol, butanol, or ethyl acetate. The TLC plate is allowed to dry before placing it in a preprepared chromatography tank containing the selected eluent (the liquid phase) with the lower edge downward. Care should be taken to ensure that the level of eluent is below the pencil line where the samples are placed; otherwise, they will simply be washed off the plate into the eluent and will not travel up the plate. When the eluent has traveled to near the top of the plate, the plate is removed and the run is complete: the spots of dye will cease to move. The individual dyes present in the inks are visible as colored spots up the plate and are each positioned at a fixed place characteristic of that particular dye. Their position can be recorded by comparing them with a standard ink containing known dyes and run on the same plate. By running two or more inks side by side, a comparison of the components can be made by direct observation. Further examination of the plates under different lighting conditions can be made so that luminescence under ultraviolet and under visible light provided by a laser or more conventional sources can be compared. The inks can also be run using other eluents.

Some indication of the relative proportions of each component is obtained by direct observation, but further examination with a densitometer can provide quantitative information about the proportion of each dye in the formulation. The colored spots will fade with time, so a photographic or similar record should be made to preserve the result for later analysis or demonstration. Recent work has developed a semiquantitative method for recording the results with image analysis and claims to be able to discriminate between blue ballpoint inks with a 92% success rate.[19] Further developments of the technique have sought to standardize the collection of spectra and increase the discriminating power through an inks library,[20] although for most purposes, a basic and inexpensive TLC setup is all that is required.

Thin-layer chromatography is not suitable for those inks that use pigments instead of dyes, such as many gel pens, as the technique compares only soluble components of the ink.[21,22] For these, other chromatographic techniques must be employed.

High-Performance Liquid Chromatography

Instead of the solution of the ink being evaporated as a spot on a chromatography plate, it can be forced by high pressure through a column of absorbent material in a glass tube that, like that of a thin-layer chromatography plate, will slow down the passage of each component to a rate that is dependent on its physical properties. As each component will be retarded to a different degree, a separation is again achieved. Instead of leaving the dyes on the column, the pressure is continued until they have all passed through the column. They are detected as they emerge by a device that measures their absorption or color at a particular wavelength or at a number of wavelengths. As the absorption is proportional to the quantity of material present, a quantitative assessment of each component is achieved.

The results are obtained as a graph with peaks representing the presence and proportion of each component. The advantage that high-performance liquid chromatography has over thin-layer chromatography is in its ability to determine more accurately the proportion of the major components of the mixture of dyes. A disadvantage is that the cost of the apparatus is considerably more than that required for thin-layer chromatography.

Other Components of Ink

Apart from the dyes present in the ink dried onto a piece of paper, there are other components. The most important of these is the vehicle that, in the case of ballpoint inks, is a mixture of resins with traces of the solvent in a recently applied ink line. In water-based inks, there is a much smaller amount of vehicle. The very small amounts that are present on the surface of a written document are insufficient for any practicable comparison to be made. Although the amounts of dyes present are not appreciably greater, their strong absorption of light and other optical properties make their examination easier. One exception is that erasable ballpoint inks contain a thermochromic ink that contains a rubber-based compound to facilitate erasure. This is sufficiently different in appearance under a microscope from conventional vehicles to be distinguished from them.

Further Techniques

Apart from the methods for testing inks described above, research into different techniques is carried out by document examiners, in universities, and in other institutions, and is described in papers published in scientific journals. Some of these are listed at the end of this chapter. Fourier transform infrared, Raman spectroscopy, and methods depending on mass spectrometry have been reported and may well become routine in the examination and comparison of inks, but at the time of this writing, they are not universally employed.

Relative Aging of Ballpoint Inks

Distinction between vehicles can be made by exploiting the ease of detection of coloring material. The solubility of dried ballpoint inks in certain solvents is dependent on the length of time that the ink has been on the paper. It is possible to test how soluble an ink is by dissolving it and measuring the amount of color that has been extracted in a certain time. By taking samples of solution at intervals, say, one and two minutes after the dried ink has been introduced into the solvent, the rate of dissolution can be determined. If the rate is faster for one sample than for another sample of the same ink on the same document, this indicates that the first sample has dried to a lesser extent and has therefore been on the document for a shorter time. It is important that like be compared with like. A different ink or a different surface would give a result that could be misleading. It is possible for inks aged between a few weeks and about nine months to be usefully tested.

The method is of value, therefore, only when the times of writing of two similar inks on the same document are in dispute. This is likely to occur if an extra sentence is suspected to have been added, so before attempting to test for the relative aging of inks, it is necessary to test them by the methods previously described to determine whether they are of the same formulation. If they are, the solubility tests will be of value; if they are not, the problem may have been solved by the difference between the inks, which could provide evidence that all was not quite straightforward. This technique is not yet universally employed.[23–26]

Dating of Inks

The relative aging of ink cannot put a precise time on the act of writing. This is not possible by any other means of ink analysis, but if an ink can be shown to have been made only after a certain date, any writing made with it cannot have been made before then. The principle has been applied when the dates in question have spanned the introduction of a new type of ink, from ballpoint pens, for example. With the wide variety of different ink formulations and the many manufacturers at work today, such dating methods require comprehensive records and cooperation with ink producers so that well-founded information is made available.

In the United States, the Laboratory of the Bureau of Alcohol, Tobacco, and Firearms of the US Treasury has built up such a collection of ink formulations, now held at the University of Lausanne,[19] but this appears to be unique. In addition, the same laboratory has arranged with producers of inks in the United States to "tag" their products with special chemicals to indicate the year of manufacture. These compounds, introduced in very small proportions, can be detected only by special sensitive analytical procedures. Their presence also provides another means of distinguishing between two inks where such a comparison is significant.

The relative timing of different entries on a document can be determined by a variety of other means. These are dealt with in Chapter 9.

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The Examination of Printed and Photocopied Documents

8

Introduction

Printed documents are frequently involved in crime, but the printing itself is rarely in dispute. However, where the whole document is suspected of being counterfeit, the forensic document examiner needs to understand how it may have been produced and what other documents must have been required for its production. It is important to identify the method of printing, whether it is by letterpress, lithography, laser printer, and so on. Many examinations involve comparisons of genuine documents with suspected counterfeits, so there is a need to compare methods and quality of printing as well as the inks or toners used. It is sometimes necessary to determine whether a number of printed documents all originated from the same source. It may be necessary to show, if a document differs from the genuine product, how it has been printed and from what original it has been copied. In other cases, the plate or some other part of the printing press can leave evidence that it was the source of the counterfeit. Photocopies present other problems; the original material copied may need to be established, or the make of copier used, or the individual machine may require identification. Images produced by scanning and subsequent printing have much in common with photocopies but also present their own problems.

To allow proper evidence to be deduced from the document in question, some knowledge of the printing process is necessary. Certain questions can be answered only by a printing technologist, but in many investigations, the document itself and its scientific examination will provide adequate evidence when the observations are interpreted properly. The main methods of commercial (or traditional) printing, including the ways in which the products can be recognized, will be briefly described at the start of this chapter. Printing inks and their examination are also considered. We then go on to discuss the examination of non-impact printing such as inkjet and laser printing (which we have termed "office" printing) and finally some of the less-commonly encountered printing methods.

Photocopies and scanned images play an increasingly large role in modern life and in those areas that are of interest to courts of law. How they are produced, how they are examined, and what can be ascertained from their examination are discussed within the electrostatic printing section.

Traditional Printing Methods

Letterpress Printing

The simplest method of transferring an image to paper, and the one that for many years was the only method, is known as relief printing or letterpress. The image is raised above the background, inked, and then pressed onto the paper. As only the raised area receives ink and touches the paper, the appropriate design is transferred to the paper.

Many forms of relief printing are in use. The traditional method of building a "form" from movable type and using a flatbed press may still be employed to make posters, letter headings, and similar documents produced in relatively small numbers. The same method can be used to print counterfeit documents. A wide range of typestyles are available, and the correct ones can be found to produce a good copy of an original.

More elementary forms of letterpress printing are those made by rubber stamps, post office cancellation stamps, and toy printing sets. These can be of considerable interest in many cases involving questioned documents and are dealt with later in this chapter.

Lithography

Lithography was invented at the end of the 18th century. It originally used a special absorbent stone as a printing plate, hence its name. A water-repelling substance was painted on the stone so that it produced the image in reverse on the surface. The stone was treated with water, which moistened the areas only where it was not repelled by the coating. A greasy ink was then applied to the surface, but did not adhere to the damp areas, only to those where the water repellent substance was. By means of pressing the selectively inked stone onto paper, the ink was transferred and the image printed.

Modern lithographic methods use plates made by photographic processes or directly from an electronic file. The plates are prepared by projecting an image onto a sensitized coating that reacts to light. After development of the plate and suitable fixing treatment, the areas to be printed are made water repellent, while those that are not to be printed become water attractive. After the plate is inked, the image is transferred first to a blanket (known as offset printing) and from that to the paper. The image to be printed is usually offset onto an intermediary rubber blanket so that the paper (or other support) does not come into direct contact with the plate itself. The flexible rubber blanket allows irregularities in the material being printed to be corrected and prevents damage to the original plate.

Offset lithography is now widely used in commercial printing both in black and white and in color. Because it depends on simply produced images to produce its plates, it is cheap and can be easily employed to copy other documents. It is therefore easy to use for making counterfeits. Color printing is achieved by using separate plates for each color to be printed. The most common setup is four-color printing using cyan, magenta, yellow, and black plates. The plates are made using the imaging process above, but color separation is done by using different filters for each plate. The images thus formed are broken into small dots (known as screening or halftone printing), and the different shades of color are achieved by mixing the colors in different proportions on the final image. In theory, only three colors are required to produce an acceptable color range, but black then requires all three colors to be printed in the same place, which is difficult to achieve and expensive on ink. Hence, a separate black plate is used. Where high-quality printing is required, such as fine-art prints, then the number of colors used can be increased; 6-color work is relatively common, but some machines have the capacity for 12-color printing. This sort of machine is unlikely to be used for counterfeiting.

Lithographic four-color printing machines are relatively cheap and can be the size of a large office photocopier, all four plates being present on the same machine. The key to good quality printing is getting the water/ink balance right on each plate, and also getting the four plates in register. Because of this, there are often a lot of waste prints produced while getting the machine set up. For a commercial printer, this is acceptable; but for counterfeiters, the amount of correct paper available may be limited, so they will be more likely to use poor-quality prints. The advantage of lithographic printing over office copiers and laser printers is the size of the print run. Short print runs are more expensive, but once set up, they can produce tens of thousands of copies, and the unit price becomes increasingly lower. Another consequence of the lithographic printing method is that the image cannot be altered without changing the whole plate. Therefore, numbering, changing the date, changing the addressee, and so on is not easily achieved. For these reasons, a counterfeiter is unlikely to use lithography for counterfeiting one-off documents; however, where double-sided, high-volume, high-quality work is required, such as currency, it still has a number of advantages over laser printing or inkjets.

Gravure

Letterpress printing is produced from a surface raised above its background, and lithography uses a flat plate. In contrast, gravure uses an image carrier where the design to be printed is below the surrounding surface. The plate is inked, and the ink on the surface is scraped away with a blade, called a "doctor blade." The only ink remaining will be in the depressions, and when the plate is pressed onto paper, the ink is transferred in the shape of the image. Gravure, or intaglio, printing is commonly used for high-quality products, especially for full-color pictures.

The plates are produced by two methods—engraving and photogravure. Engraving is used in bank notes and other high-grade security printing, and the plates are made either by hand or with the aid of machines. The method produces designs and lettering in solid lines but is limited in that pictures cannot be reproduced.

Photogravure is much more widely employed. It depends on the image to be printed being projected onto a light-sensitive plate. Where light falls on the surface, a chemical reaction takes place. The surface is treated with an appropriate developer so that the areas where no printing image is present are made resistant to acid; then, treatment with acid etches depressions in the image areas. The acid-resistant material is removed, and the surface of the plate is then highly polished so that all excess ink can be removed from the nonprinting areas.

Because the ink that is to be transferred to the paper has to be held for a short time in the depressions in the plate, large areas cannot be printed without a further operation. A grid is placed between the picture to be printed and the light-sensitive plate so that, instead of solid areas, a series of small cells is etched on the surface. When the design is printed, the ink from the cells overlaps so that a continuous tone is produced. By varying the depth or width of the cells, different densities of color can be obtained. Full-color printing is achieved by the methods described for lithography using three or more colors, each on a different plate.

Raised Printing

Embossed printing is raised from the surface of the paper. It is produced by two plates, one with the image to be printed in relief and the other with the image depressed into the surface. The depressions are inked and the paper is forced into them by the relief image. The result is the transfer of a much larger quantity of ink than is normal in other methods of printing.

Thermography is a technique that produces similar effects, but by a different process. The image is printed with a slow-drying ink, which is then dusted with a resinous powder that sticks to the wet ink. The paper is then pressed through a heater and the powder fuses and swells, giving a raised effect.

Screen Printing

Screen printing depends on squeezing ink through a mesh made of nylon, silk, or other materials. The nonprinting areas are covered with a stencil so that only the uncovered parts of the screen allow ink to pass through. The method is used for short runs. Its main advantages are that thick coatings of ink can be transferred, and it can be used on fragile surfaces, as little pressure is employed.

Identification of Printing Methods

Observation of printed material with, when necessary, the aid of a microscope can give an identification of the method used to produce it because the type of plate, relief, lithography, or gravure will produce characteristic effects on the surface of the paper. The type of ink used can also give an indication of the printing process; this is dealt with later in this chapter.

Letterpress

Letterpress or relief printing depends on raised type transferring ink to the paper. To do this, considerable pressure is required. The ink applied evenly to the typeface is pressed onto the paper, where it is partly absorbed and partly retained on the paper surface. The evenness of the ink on the type may not be retained when it is transferred to the paper. The pressure may force it outward toward the edges of the letter, where it escapes and settles. This gives an excess at the outlines of the printed letter that is more apparent when letterpress printing is made on a shiny nonabsorbent paper. The effect is known in the printing industry as "squash."

The pressure exerted where the typeface touches the paper may cause indentations on the surface, and these may penetrate into the paper so that they are visible or tactile on the back. Examination with oblique lighting or by touch will reveal that the paper surface is not smooth, but rather is indented by the printing. A combination of uneven inking or squash with indentation of the printed lettering is indicative of letterpress or relief printing. Without indentation of the surface, care has to be taken that printing with visible squash lines has not been made by a photographic process, reproducing a letterpress original. It is possible in these circumstances that the uneven inking of the original has been faithfully copied. A further complication is that letterpress is often "offset"—that is, the image is transferred from the raised surfaces to the paper via an intermediary rubber blanket. While the squash lines will still be apparent, there is no direct contact between plate and paper, so no indentations will be seen.

Lithography

Lithographic methods depend on the deposition of ink from a flat surface, the plate carrying in reverse the pattern to be printed. As there is no difference in pressure between image and non-image areas, no indentations are found. The ink is evenly distributed through the printed matter with, normally, no concentration at the edges.

Because of the dependence on photography for the preparation of plates, the processes used cause the image to lose some of the detail of the original.

This is most apparent when sharp corners and edges of clear printing are copied. These become rounded and tend to lose their definition, sometimes to the extent that small lettering will become indistinct. These features are typical of lithography, but in well-printed material, the lack of sharpness is apparent only under microscopic examination.

Gravure

Gravure is now used to print good-quality material and is capable of halftone printing, which allows shades of color to be produced. Therefore, a variation in the thickness of the ink on the paper is an indication of this method of printing. The cellular method of producing areas of tone leaves signs of separation at the edges.

Printing Inks

Methods of Examination

Ordinary printing inks differ from those used in pens in that they are oil based and have a high inorganic content. For the most part, they do not react to the tests for writing inks described in Chapter 7, but the nondestructive tests involving reflectance and luminescence in different lighting conditions can sometimes differentiate one from another. Although they are mostly insoluble in any of the solvents used as a preliminary to thin-layer chromatography, other tests can be used to distinguish between them. The binding agents can be tested by the techniques of pyrolysis mass spectroscopy or infrared absorption spectroscopy, and the inorganic components can be determined by a variety of methods ranging from emission spectroscopy to microprobe electron microscopy (see Chapter 10). As in other methods of forensic science, the first tests to be performed are those that do not cause damage. Only if these do not provide an answer are those requiring samples of ink to be taken then applied. Modern analytical techniques require only small quantities of material, so little damage is done to the document being tested.[1,2]

Some inks can be tested by much simpler techniques, particularly when security documents and banknotes are being examined. The inks used are often infrared or ultraviolet sensitive, and there may be images printed on the document that are only visible when subjected to specific lighting conditions. There are also inks that will reflect differently at different angles, luminesce, or appear different colors depending on the type of light used for illumination. The first port of call for a document examiner is therefore to run through all the nondestructive lighting techniques available. As in any other examination, it is important to compare like with like, and a questioned document must be compared with a genuine document that purports to come from the same print run. There have been instances where a document has been deemed to be counterfeit because a UV image is missing, only to find that it is a genuine document from an earlier print run. As is repeated elsewhere in this book, observation is only part of the examination; correct interpretation of what is seen is what provides expertise. Water-soluble inks are used for background on security documents because they are removed when attempts are made to erase entries by chemical means. A drop of water applied to the surface will dissolve the security ink in a small area but will not affect a lithographic ink on a counterfeit. Magnetic inks are commonly used to print numbers on checks to allow them to be read by machine; a counterfeit is more likely to be printed in a nonmagnetic ink. The difference can be detected by using a device containing finely divided iron particles that react to magnetized inks but not to others.[3]

The object of testing the composition of printing inks is twofold. The first is to determine whether the ink of a suspected counterfeit is the same as that used for the genuine document. Often, this is not necessary because the appearance, macroscopic or microscopic, of the printing will show clear differences, and in other cases, a different paper may have been used, which proves its spurious nature. Where a lithographic copy has been made of a lithographic original on similar paper, the discovery of a difference in ink will be of importance.

The second object of the analysis of inks on printed documents is to compare them with other counterfeits or with inks found at the suspected source of their production. Comparison of inks can indicate a possible origin, but it cannot identify with certainty the source because inks, although made in a wide variety, are usually not unique to one printing works.

Identification of the Source of Printed Material

Lithographic printing methods and photocopying processes both use documents as sources for their images. The discovery of the source of a reproduced counterfeit or copy is an important aspect of forensic document examination.

To make a lithographic copy of a document, images are made of a particular genuine document. If this is one of many, all of which are identical, there will be no indication of which one was used. However, if other marks have been made—serial numbers, written entries, or rubber-stamp impressions, for example—these will either have to be incorporated or will have to be removed at the artwork stage in the plate preparation. If they are left, their presence will provide clear evidence that a particular document has been copied, assuming this copy is still extant and can be compared. Any writing on the original could not be exactly matched to any other, and its position and the position of a stamped impression will not be precisely the same on any other possible source.

If the identifying marks have been removed during the plate preparation, the background printing occupying the same area will also be removed. It may be impossible to take out all of a signature or other written entries, especially if these cross over printed lines or patterns. The position of these signs of erasure or traces of writing can be adequate to identify the copied document. It is similarly possible to identify parts of serial numbers that have been incompletely removed. Where parts of the image have been removed or replaced electronically, detection may prove much more difficult.

Accidental marks from stains or faults in the paper or deliberately introduced variable features may be reproduced in a counterfeit and will effect a means of identification of the source of the counterfeit. An example of this occurs when the randomly spaced colored fibers introduced as a security device are photographed along with the other details of the genuine document.

In some instances, printing plates may be made up from images of more than one source. It is therefore possible to print a counterfeit with some features of one original and others of another. The presence of both sources traced to possession of a suspect would therefore be very significant.

Counterfeit documents can be compared directly with their suspected sources. Such features as signatures or stamped impressions that have been reproduced can be aligned with their originals using transparencies made for the purpose by examination under a comparison projector (see Chapter 10) or by using equipment that allows high-quality images of the documents to be directly compared.

Sometimes plates or other components of printing processes are found and can be compared with printed documents. This is best done by imaging the design as it appears on the component and comparing it with the document, for example, by making a transparency that can be compared with the document. Defects and other characteristics of the printing can link documents together and, with certainty, to the plate that printed them.

Office Printing

So far, consideration has been given to machines using typefaces that leave their impressions on the documents. In Chapter 6, the identification of fonts, spacing, layout, and other characteristics was discussed as it relates to fixed head and impact printers such as typewriters. With the evolution of the technological age, printers have changed considerably. The most common classes of printer used today are inkjet printers and electrostatic printers (photocopiers and laser printers). The mechanisms for these two classes, and some other forms of printing that may be encountered, will be discussed briefly later in the chapter. Printers no longer rely on physical print-heads impacting on the paper and therefore they can print in color and in a very much more flexible and diverse way and can be made to reproduce pictures, photographs, and graphs, as well as text in a variety of fonts, sizes, and orientations in the same document. The images they produce are made up of tiny dots, and color is achieved by printing colored dots side by side so that the eye mixes the combination to form the color required. Most printers contain the complementary colors of cyan, magenta, and yellow ink or toner cartridges so that the primary colors of red, green, and blue (and all other shades) can be reproduced (see Chapter 7 for an understanding of color). Most, if not all, printers contain a separate black cartridge because black is the most popular color for printing; it also is more economical to do this. While mixing all the complementary colors does produce black, it is often unsatisfactory due to poor registration of the dots, and it uses a lot of ink. The four-color process derives from the practices in commercial printing and, as with commercial printing, the more colors used, the better the accuracy of the color reproduction. Consequently, the document examiner will encounter some top-end printers with more than four colors.

What is printed by a modern printer (including the color, layout, and general appearance) is all controlled by a computer in the broadest sense; this can be done from a variety of devices and using a variety of software programs, limited only by the ink or medium the printer uses and by the manufacturer's specifications. Quality of print is usually measured in pixel size, or dots per inch (dpi). While 300 dpi produces a perfectly acceptable quality where the individual dots are not apparent to the naked eye, these days 600 dpi or greater is the industry standard, with top-of-the-range machines advertising 2400 dpi.

The document examiner's main focus in examining the output of these machines remains the physical manifestation of this technology. As with typewriting, the objective is to provide some information about the machine that produced the document for intelligence or investigative purposes, to link documents that have been produced on the same machine or to distinguish between the outputs of different machines, or to sequence documents to identify which may have been produced first. In doing this, it is important to understand how printed documents are generated; what differences could be the result of using a different software program; and what differences, perhaps in apparently identical documents, could be the result of printing from the same file using a different printer, perhaps in an attempt to deceive. Often, the document examiner will not have access to or knowledge of the printer that has been used or the computer that controlled it. There is no doubt that technology has made examining questioned documents much more complex and less fruitful, but by understanding the printing mechanisms and the way a document is produced, occasionally very significant findings can be brought to the courtroom, particularly where the printer has developed a fault. Research in this field has been mainly confined to examination and classification of the materials used, and there is scope for more work in identifying individual printer characteristics.

Nonimpact Printing Methods

An entirely new field has been developed with nonimpact printers. While the standard methods of printing all require pressure, sometimes very great, between the plate and the paper, these require very little contact or none at all. Electrostatic printing, where the image is transferred from a drum to paper by a change in a static electric charge, is closely allied to laser printing; other methods, such as inkjet printing, fire ink at the right places on the paper, guided by electrostatic forces.

Similar methods are used in devices related to typewriters, such as computer and calculator printers and till roll markers. At one time, there was a clear distinction between printing methods that reproduced the same information in identical documents and individually prepared, mechanically printed material such as typewritings. There is no longer such a separation because the same techniques, allied to computers, can perform both functions adequately and economically. For instance, a fax machine, once reliant on specially coated thermal paper, may now be a standalone plain-paper machine or be combined into another office machine such as a photocopier or printer, and may be produced using inkjet or laser printing. From the point of view of the document examiner, there are only two common methods of production of a questioned document—inkjet printing and electrostatic printing—and these are dealt with in the following sections. Laser printers use electrostatic printing and are covered here, while the examination of photocopies, however produced, merit a separate section of its own. At the end of the chapter, we deal with less commonly encountered, usually older, technologies that the document examiner should be aware of.

Inkjet Printers

The dot matrix principle is employed by inkjet printers, which deliver a drop of ink to each appropriate point of the matrix. Inkjet printers are the most common form of print mechanism found in a home printer. They can be used to print both black and white and color, are cheap to produce and fast, and interface with many electronic devices from phones to mainframe computers. In fact, the mechanism has been used in industry for many years; the concept of inkjet printing originated in the 19th century, with Lord Kelvin taking out the first patent on inkjet printing in 1867, and the technology was first extensively developed in the early 1950s, with Siemens marketing the first commercial devices in 1951.[4] It is ideal for printing on surfaces such as packaging, glass, curved surfaces, eggs, and so on, because the print-head does not need to contact the substrate itself, the ink being transferred through firing droplets of ink from a cartridge through the air. Because of this, the ink has to have very specific properties in terms of droplet formation, aerodynamics, and rapid drying. Hence, the inks are a vital component of the printing mechanism.

Ink Delivery

Today, most inkjet printers use one of two principal drop-on demand methods to propel ink. Thermal inkjet printers use heat to generate a bubble that creates an actuating force, and piezoelectric printers use electrically driven actuators to pump ink from a chamber to create the droplet.[5,6]

In thermal printers, the print-head is replaced along with the ink cartridge, and a brief inspection of the spent ink cartridge will reveal the rows of holes (nozzles) in a metal plate through which the ink is ejected. Turning the cartridge on its side will reveal the electrodes that control the nozzles and connect to the printer and ultimately the computer software. Faults that can develop in a print-head of this nature are blocked nozzles that will produce a thin white line in the printing or, if the blockage is partial, a misdirected dot that lies away from the intended position.[7] The latter can be characteristic of the print-head and will persist for numerous copies.[8] However, the misalignment is difficult to spot, as it will only occur when the nozzle is activated. Faults that are due to the print-head should be regarded as transient, as they can alter (cleaning the head may unblock the nozzle) and are discarded with the print-head once the ink is replaced. However, if similar faults are seen in both the questioned document and the known sample of print, they are highly significant, as they are generally rare.

A further fault that can develop is a dirty or faulty electrode. The effect of this will vary depending on the electrode—they don't all control one nozzle each. Some faults simply produce lines in the printing, as for a blocked nozzle, but others will affect several lines. Faults can be deliberately introduced on test machines by temporarily blocking each electrode with adhesive tape, which may shed light on some investigations. Again, if the fault lies in the print-head, then cleaning the electrodes or discarding the print-head will remove the fault; however, these faults can occasionally be a fault in the machine itself and will persist. Faults of this nature are very rare, but highly significant if they are observed.

The other print mechanism used in inkjets is the piezoelectric printer. In this type, the print-head is controlled by passing an electric current through a crystal, causing it to expand against a diaphragm and eject a droplet of ink. This is a more efficient mechanism and less prone to faults. Consequently, in these machines, only the ink reservoir is replaced, the print-head remaining with the printer for the lifetime of the machine. If a fault does develop, it will create a pattern of faults similar to those described for thermal inkjets (blocked nozzles, electrode malfunction), but this time, the fault may be permanent. Again, this type of fault is rare, but highly significant if it occurs.

Inks

The most important component of an inkjet printer is the ink itself. The ink used in an inkjet printer is very specialized, as it has to be ejected at around 10 meters per second, form a perfect sphere in flight, and dry instantly on striking the paper or other substrate. Desktop inkjet printers, as used in offices or at home, tend to use aqueous inks based or a mixture of water, glycol, and dyes or pigments. If the paper used is not of the right quality, these can take time to dry, causing a bleeding effect (fuzzy edge) on the paper. Consequently, a difference in quality of print between a questioned document and a control print is not an indication that a different printer has been used, just a reflection of the quality of the paper. Aqueous inks and dyes tend to be used in thermal inkjets; printers that claim waterproof, "archive-quality," or smudge-resistant print will use oil-and-pigment–based inks. There are also solid, plastic inks used that are held in a liquid state in the printer and fired through nozzles as droplets as before, but solidify on contact with the substrate. These will have a more waxy appearance under the microscope. It is apparent from this discussion that inks are very specific to a type of machine and a manufacturer. While some of these differences can be seen on inspection of the different outputs under a microscope, a more reliable way of analyzing the ink must be found. The inks can be conveniently analyzed using the analytical techniques described in Chapter 7, particularly UV-visible light absorbance and TLC.[9–11] However, to extract all the materials involved in the production of the ink, specialized techniques have been developed.[12] If a difference in inks is established, then this is likely to be due to a different printer. If the inks are similar, then this is evidentially much less useful, as many printers will use the same ink.

The ejected ink droplet usually has a comet shape with a long tail.[5,13] The head and tail can separate during travel, the head becoming a separate drop and the tail forming two or more satellite drops. The result of these satellite drops severely effects the printing quality of the print-head, causing

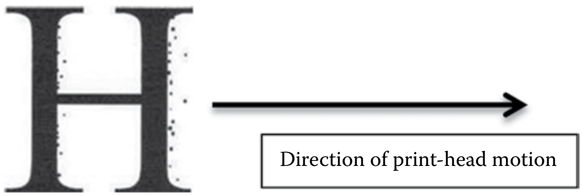

Figure 8.1 Ink spatter can determine the direction of travel of the print head. It predominately occurs on the side of the printed character in the direction the print head is travelling. Thus, if the bulk of the spatter is on the right of the character, then the print head was traveling from left to right.

the appearance of ink spatter, shown in Figure 8.1. Ink spatter is a property of the printer and the ink in combination and is not seen in all printers. Further, print-heads will travel in one direction or another depending on the software they are controlled by, and ink spatter is always on the side of the character toward which the head is traveling. Inconsistencies in the direction of travel and the way a machine produces a print of the same document may suggest a different machine or machine/software combination. (Figure 8.1)

Examination of Inkjet Printers

As has been discussed, much of the appearance of an output from an inkjet printer is controlled by software and not the printer, and many of the features, such as the print quality and the inks, are generic and common to many different printers. Where differences in ink or print quality can be established and the substrate can be eliminated as the cause of the difference, then it can be concluded that a different printer has been used. Where similarities exist, then while the documents could have been produced on the same printer, the examination is essentially inconclusive—many printers could also have produced the document.[13] Only on rare occasions are there individual faults that are due to the operation of the individual printer, but on these occasions, those similarities can be highly significant.[14] Many faults on inkjets are transient and last until the print-head is cleaned or discarded. On these occasions, it is necessary to understand the cause of the fault. This means that they do not often provide sufficient evidence to identify an individual machine. In these cases, comparison of the questioned document and one produced by the machine will produce inconclusive evidence that the machine was responsible and does not exclude the possibility that one machine may have been used to prepare the questioned documents.

Occasionally, a specific unusual fault in the mechanism of the printer will produce an aberration in its product. Investigation of the machine itself will discover the cause, but such examinations are not common.[14]

Electrostatic Printers: Laser Printers and Photocopiers

Laser printers depend on points of light charging a drum similar to that used in photocopiers based on electrostatic printing. A photosensitive drum is charged electrostatically and then partially discharged by laser in areas corresponding to those where printing is not required. Toner applied to the drum adheres to the remaining areas and is transferred to the paper and fused to its surface.

The characters and their style are controlled by computer and no fixed typeface is employed. Because of this, the methods of identifying an individual typewriter cannot be used, but faults that are often found on the drum can be reproduced on the page. These appear as small marks and can be discovered by careful observation. They are reproduced more than once because the circumference of the drum is less than the length of a typical page, and their regular repetition indicates that they originated from the drum.[15]

Photocopying

Photocopiers are related to photography in that they reproduce an already existing document and originally required special sensitized paper. A number of different techniques were employed, but methods employing static electricity became the most widely used. The principle is that certain substances that have been charged with static electricity will discharge in those areas on which light falls. If the light is a focused image of a typed page, only those parts of the surface where the typewritings appear will remain charged because they remained unilluminated. The surface is sprayed with oppositely charged particles, which are attracted to the charged areas and therefore print out the image.

Electrostatic Printing (Xerography)

Electrostatic printing, also known as Xerography after the inventors of the process, differs in that the image is projected not onto the paper but onto a previously charged drum or belt that has been specially coated so that it, too, will discharge when illuminated. Charged toner powder then forms the image on the drum, and this is then transferred to normal untreated paper and fused onto the surface. Plain paper copiers have now replaced those requiring coated papers. Transparent film can be used instead of paper, providing another advantage of Xerography. Full-color photocopiers scan the document with white light, and color separation is achieved by using different filters to get the cyan, magenta, yellow, and black print images, which are then developed using the respective colored toners.

Laser Printing

The method used in plain paper copiers—electrostatic printing—uses the principle of laser printing. In copiers, the image on the drum is formed by a projection of the document being copied; in laser printing, it is made by many thousands of impulses of laser light.

The area on the drum from which the page is to be printed is divided into a grid with many extremely small squares. The laser beam scans each row successively, and each square of each row either receives an impulse or not, depending on the signals given to the laser. The minute squares on the matrix are therefore discharged by laser light or remain charged. When toner is applied, it is attracted by and adheres only to those areas that retain the charge.

Whether a square receives an impulse is controlled by a computer, which can be programmed to produce an enormous variety of printed material. The printer is not confined to one style of type but can create as many as the computer can manage. In addition, the printers have the capacity to change parts of the printed material so that they are different for each copy, while the rest of the text is the same.

The Examination of Photocopies

Photocopiers and scanners are now widely available and are increasingly used to produce documents illegally or with intent to deceive. As with the examination of printing inks and printed materials, the examination of toners, the photocopies themselves, and documents that may have been copied provides invaluable information for an investigator or a court.

Photocopy Toners

The printed images of plain paper copiers and laser-printed documents are not produced by liquid inks drying on the paper but by resinous particles fusing or compressed on the surface. The effect is therefore very different. Plain paper copiers use dry toners, which are, when forming an image on a photocopy, built up on the surface rather than partly absorbed in it. Unlike conventional printing inks, whose appearance under magnification will not vary greatly, especially when one type of printing is considered, different toners can be distinguished by microscopic means.

Ordinary low-power magnification can detect differences in the morphology of the fused or compressed toner, but a greater distinction can be made by using a scanning electron microscope. Using magnifications of around 1,000 or 2,000×, the structure of the toner surface can be examined and a distinction can be made between one toner and another.

Further tests can be made to ascertain the chemical composition of the toner. A scanning electron microscope can again be used, this time to determine the elemental composition. Pyrolysis mass spectroscopy and infrared spectroscopy are used to identify or compare the organic resins that are an integral part of all dry toners. Iron-containing toners can be distinguished by their susceptibility to being magnetized. Apart from the latter, which is nondestructive, these tests require a very small quantity of material—less than a square millimeter—and they can show whether two toners are similar, or they can identify the manufacturer. It is not possible by these means to identify a particular machine, merely a type of toner and therefore the probable make of machine. Although it is not impossible for a toner to be used in a machine for which it was not designed, this does not often happen; most toners are packed in special containers made especially for a particular model of photocopier.

Historically, some plain paper copiers use liquid-based toners, which leave an image with an appearance not unlike that of lithographic printing. They deposit a smaller quantity of material, which is less easy to identify. Other copiers use specially coated papers, but these are becoming less popular and are being replaced by plain paper machines. Specially coated paper copiers usually depend on a film of zinc oxide on the surface, but different manufacturers use different formulations. Analysis of the inorganic components of the coating can determine the type of paper and therefore, normally, the type of machine. While a document examiner is unlikely to encounter these methods in day-to-day comparisons, they may turn up in cases involving documents from the mid to late 20th century.

Machine Characteristics

Apart from the analysis of toner, which gives an indication of the type of machine used to produce a copy, extraneous marks on a copy can provide additional information. These fall into two classes: those that, like the composition of the toner, can identify the make and model of a photocopier and those that will identify the individual machine used to make the copy or that was instrumental in its preparation.

A photocopier depends on mechanical means for handling the paper. These can leave characteristic marks on the copies and therefore give an indication of the model used. They range from indentations caused by grippers or rollers to marks made by toners in certain parts of the copy. If the page being copied does not fill the area allowed for it, parts of the cover can be copied; this may give a clear indication of the type of machine used.

Photocopiers do not produce copies of exactly the same size as their originals. There is usually a slight change of around 1% in the copy, which is not necessarily the same in each dimension. Many copies are capable of much greater magnification as well as reduction. These properties can also show the type of machine used.

Linking a Photocopy with a Photocopier

Apart from those marks that are characteristic of a model, other marks appear on a copy caused by dirt, damage, or malfunction of the machine. These can arise from scratches, dust, or other material on the platen, the glass plate that supports the document being copied, on the lid that covers it, or on the drum on which the image is first formed. Other problems can also occur, such as defects in the corona wire that charges the drum or in the mechanism that puts toner onto it.

Marks on the platen, lid, or drum can be permanent or temporary. Even those described as permanent can be removed if the part itself is changed. Those on the platen will occur each time a document is copied, those on the lid only when it is exposed by an incomplete covering of the platen, and those on the drum regularly but not necessarily at the same frequency as copies are produced. This means that such marks on the drum may show at a different place on successive copies or not at all on some, depending on the diameter of the drum.[16]

Defects in charging, application of toner, and transport of paper will show as extra lines down the paper or in poor copying in places on the page. They are normally temporary because the faults that cause them are usually soon rectified.

The most significant marks are those that are randomly formed by dust or damage. These give specks or dots anywhere on the copy and sometimes form groups rather like constellations of stars that are easily recognized on all copies on which they occur. These "trash marks," as they are sometimes described, may be produced for a long time, or they may be completely or partly removed or added to. Therefore, although all such marks on two photocopies may not match, a reasonable number that can be easily superimposed, by the use of either photographic transparencies or a comparison projector, is clear proof that the same machine has been used in the production of both. Their random nature indicates that chance match is extremely unlikely.

In some cases, the period during which a copy was made can be established because there is a gradual change in the pattern of the marks. It is also possible to establish that a copy has been recopied on the same machine if the constellation occurs twice on a document.

The presence of characteristic marks on a photocopy does not indicate that it must itself have been made on the particular machine. It may be a copy of another that was made on that machine, the marks having been reproduced along with the rest of the information. Some photocopies exhibit marks from more than one machine, indicating that copying of a copy has taken place, but with clean equipment, there may be little to show this. Testing of the paper and toner can then assist in establishing if the copies have different origins. Color copiers, and some color laser printers, add latent images, which are different for each machine, onto the color copies they produce. This enables the manufacturer to identify the individual machine used to make the copy.

The Identification of the Origins of a Photocopy

The document reproduced by a photocopier is very often clearly identifiable. A handwritten letter is unique, and its photocopy could not have had another source; the same would apply to a typewritten document, which cannot be retyped in exactly the same form because of the variability found in the output of a typist or a typewriter but not necessarily in a computer-printed document. Many photocopies are, however, made from copies rather than originals, and it is therefore important to show which copy has been the source.

The methods used to solve this problem are ones of logic and common sense. It is in the differences that can be detected between the possible sources that evidence can be found to associate a copy with an original. Written marks made on a copy will not be identical with those on any other, so if these have been photocopied, the document that bears them must be the source. If they are not present on the copy, their host document cannot be excluded; they could have been made after the copy was made.

Apart from writings, other marks on a document may be copied. Staple holes, folds, tears, stains, and adventitious inclusions may all be reproduced. Their absence may or may not be proof that the document on which they are found was not the source, depending on when the feature may first have appeared. Faults in the manufacture of the paper are clearly more significant than the staple holes or tears.

When a number of copies of a document are made by various reproductive methods including photocopying, small differences can be found between individual copies of the batches. Some parts may be imperfectly copied, there may be some smearing of ink or toner, marks on a photocopy originating from its drum may be recognized, or the trash mark pattern may be slightly different within the batch.

When a batch of copies is investigated to determine which one of the batch has been recopied, the original document must also be regarded as a possible source. It is possible that the document is a first-generation copy. The slight magnification produced by the reproductive process can be measured to give an indication of how many stages have been made, but as machines do not enlarge to the same extent, care has to be taken in such calculations. Folding and creasing of a document can also be a factor in the size of a copy. Creases will reduce the dimensions of a document and confuse calculations of enlargements caused by photocopying.

When photocopies are made, it is possible to blank out certain parts by covering them with paper or correction fluid, the former temporarily and the latter permanently. Absence of features that must have been present on the original does not therefore exclude the possibility that it may have been copied. In some cases, the obliterating material, or its edges, will be apparent, but this is not always so.

Facsimile Machines

The facsimile machine, or fax, produces documents that can be the subject of investigation and litigation. As fax copies are timed and dated and there is a record of transmission, they can form an important part of a transaction and therefore can be subject to question. These days, a fax can be generated electronically, and the printed document may be produced using a variety of printers, from inkjet to laser printing. Basically, the process of producing a fax is similar to that of a digital photocopier, using either coated or plain paper, the original document being copied at a distance from its source. Most dedicated fax machines can be used as photocopiers, but the quality, dictated by the need to transmit the digital data reasonably quickly, is sometimes not as good as that of a conventional photocopy.

A number of questions that can be addressed by the document examiner can arise from a disputed fax. The origins of the sending machine or the receiving machine may be of importance, and whether the fax is the first copy or a fax of a fax may be significant.

Normally, a fax is received with a line of data from the sending machine at the top or bottom, which is referred to as a transmitting terminal identifier (TTI). This contains information about the sender and can be programmed to include the name and telephone number or other material as well as the time and date on which the fax was sent. It is possible for this to be removed from the machine by suitable adjustment, but in many cases, the make of the sending machine can be determined from the number of characters as well as their style and position. Collections of TTI fonts are necessary for this; one organization, the American Society of Questioned Document Examiners, has arranged such a collection for its members. TTIs can be removed by cutting them off, and another line can be substituted by pasting it in the appropriate place. A photocopy of this composite may be mistaken for one of the original fax. The methods used for detecting composite photocopies are appropriate in these cases. The characteristic appearance of a fax made up of individual printing areas, referred to as pixels, is similar to that of a laser printer, but with coarser resolution due to the larger pixels employed. If a TTI is substituted, it will have the same appearance as the faxed material, unlike the genuine

TTI, which is not produced by the matrix method but is generated in the transmitting terminal.

As with photocopiers, dirt can be reproduced on a fax. Because each line of pixels is separately scanned, a fragment on the scanning window will be reproduced as a vertical line, beginning below the TTI but not on it. This is a temporary feature that can be removed by cleaning.

Claims may be made that faxes purporting to be first generation are faxes of other, previously sent, faxes. This can be determined by the appearance of the individual pixels under magnification, where a copy of a straight line as in a first-generation copy differs from that of the individual pixels in a second copy.

Fraudulent Photocopies

Unlike conventional printing presses, photocopiers are easy to operate and can be handled by nearly anyone. Their use has grown enormously, and in recent years, plain paper copiers have become capable of producing copies of high quality not obviously distinguishable from the original documents. The popularity of the medium has meant that photocopies are accepted without question and may take the place of originals in many transactions.

This has led to the practice of producing a photocopy that appears to be one document but is made up of parts of two or more documents, perhaps with some parts of the writing or typing deleted. The preparation of such composites is not difficult. Signatures can be cut out of one letter and added to another. Printed headings can be used by blanking out the rest of a letter. Parts of typewriting can be covered and replaced on a copy with other typed material, completely changing the meaning. Recopying the prototype produces a copy that appears to be of a single letter.

Edges of covering paper do not always show when the combination is reproduced, and correcting fluids that rapidly dry to give a white coating are often not reproduced on photocopies.

In some modern photocopiers, there is an "overlay" facility that allows a composite copy to be made without the need to cover part of the document with another. However, such documents are now more likely to be made by scanning the source documents into a computer and then electronically cutting and pasting the required element into a new document, which is then printed.

By these means, it is possible to produce a photocopy that shows no evidence that it is other than a reproduction of one original document. Because of this, a photocopy should never be accepted as an authentic record of a transaction or agreement without other evidence that it is genuine.

Although in some cases, it is impossible to say that a copy is other than genuine because it leaves no evidence that it is a composite, in others, clear signs can be found to establish fraudulent composition. These arise because of the difficulty encountered in, for example, eliminating all signs of paper edges, correctly aligning added text and headings, and ensuring that all added material is complete.

The evidence that a copy is not of a single document is provided, therefore, by such features as thin lines around, over, or under a signature or other added material; headings and text not in alignment with each other; text different in style from or not correctly positioned in relation to others; parts of signatures missing or containing the remains of other writing that the original once crossed; and different parts of the document having slightly different background tones, especially where an image has been inserted. In some cases, the fact that the final product contains material that has been copied twice is shown by the presence of a double trash mark pattern produced by the copier.

Other clear proof of the fraudulent nature of a composite photocopy can be obtained from the discovery of the source of the components. A signature will never be exactly reproduced when it is written again, so if one on a document precisely matches that on a photocopy, the latter must be a copy of that signature and no other. If the original is on a document not the subject of the copy, then the other copied material is not genuinely associated with the signature. Similarly, if part of a typewritten text exactly matches original typewriting, or perhaps a carbon copy of it, but part does not, then the copy cannot be of a single document.

These features are unlikely to be noticed by a recipient of a fraudulent photocopy, which may in any case not provide any of them. It is sometimes necessary for the document examiner to testify that although he cannot find any evidence that a photocopy is not genuine, that possibility is very real. There are occasions when it is impossible to conceive how a photocopy could have been made from more than one source. These occur when the writings and typewritings are overlapping to the extent that no division or addition could be made without leaving incomplete parts of letters or words. In the absence of such evidence, the assumption must be made that any photocopy cannot be excluded as a possible composite.

Other Printing Methods

Information can be transferred to paper by methods other than handwriting or typewriting or by conventional printing and photocopying. Stamps bearing signatures or many other designs and information, date stamps, machines that stamp numbers consecutively or print prices or times on tickets, and toy printing sets are all instruments used on documents of interest to criminal and civil courts. In addition, dry transfer methods of placing lettering and other designs by transferring them from paper charts may be employed in documents of forensic interest. A further method of introducing information to paper or other surfaces is by the use of lettering tape, on which the impressions of words are stamped before being stuck onto the document.

Dot-Matrix Machines

When considering the main classes of office printer (inkjet and electrostatic), it is worth discussing the evolution of printing through dot-matrix printers. They are still encountered today, as they are cheap and robust, and they form a bridge between the old technology (typewriters) and the modern day.

Instead of producing a complete image of a letter or other character in one stroke, the shape is built up of individual dots. The matrix used to produce a character creates rows of columns, a rectangular pattern not unlike a miniature chessboard. Instead of alternate black and white squares, the areas are made black or white in the shape of the character to be printed. In fact, the areas are not squares, but dots that are produced in a number of different ways.

The simplest method is similar to a typewriter; impact dot matrix printers use a vertical column of pins mounted in a head that moves horizontally one space at a time. As it progresses, different combinations of pins project to strike the ribbon so that it marks the paper. If a letter *L* is being printed, the first space employs all the pins and the next few use the bottom one only. This is a simplified description, because, depending on the complexity of the letter and the number of pins available, many different styles of lettering can be produced. In thermal dot-matrix printing, a head containing the matrix is pressed onto a special ribbon or paper that forms a dot when a point of the matrix is heated, but does not do so when it is cold. The most common dot-matrix printers encountered today are 9-pin printers, but 7-, 12-, and 24-pin can also be encountered.

The appearance of lettering produced by dot-matrix machines varies, depending on the number of positions in the matrix. In those that do not claim to be of high quality, the dots are clearly visible and separate from each other. When machines containing a larger number of dots are used, these are less obvious but can be identified under the microscope, particularly on diagonal lines where the dots are more clearly seen.

The appearance of the material making up the dots is indicative of the method used to form them. Normal fabric ribbon is used for mechanically operated pins, while in thermal printers, a heat-sensitive ribbon produces a deposit, not unlike the appearance of photocopy toner, that appears to be raised from the surface of the paper. In some thermal printers, it is the paper itself that is thermally sensitive and the dots appear as small darkened patches of paper. When thermal paper is used, excessive exposure to heat will turn the whole sheet or role of paper black.

In the examination of the outputs from dot-matrix printers, the document examiner is usually asked the question, “Did this machine produce this document?” Clearly, the shape of the letter is of much less value, as it is dictated by the controlling software and the number of pins. However, these machines can suffer from misalignments, just as typewriters can. The pins can become permanently bent, resulting in consistent blank lines appearing in the print, or they can become loose, resulting in inconsistent but recurrent blank lines. They can also fail to fire, resulting in a broader white line and poorly formed characters. While these can be characteristic of an individual printer, the chances that a similar fault occurring in a different printer and giving a similar appearance, are quite high, particularly if it is one of the more heavily used central pins which is causing the problem. Conclusions regarding dot-matrix printers are often qualified for this reason.

Other methods of printing include a dot-matrix printer that employs electrical sparks from points on the matrix, which affect a metallic paper surface. These are mainly used in cash registers or similar machines; the special paper would be unsatisfactory for normal documents. The misalignment of the dots in an adding machine has provided useful evidence in one reported case.[3]

A different principle is used in other computer-controlled machines. A battery of four small rollerball pens, each containing a different colored ink, is mounted in front of the platen holding the paper. Any one of the pens can be made to make contact with the paper while it is moved to “draw” the appropriate character. Different styles and sizes can be selected and graphics produced. The method of production of machine writing is very flexible and inexpensive and may increase in popularity. Microscopic examination of the products of this type of machine shows a characteristic pattern of continuous lines or elongated dots.

Stamped Impressions

Stamps designed to transfer inked impressions are made either of metal or rubber compounds and are still widely used in situations where official authorization or a portable date stamp is required, for instance, for the import/export of goods at ports or in passports at remote border locations (the UK post office cancellation stamps used to be made of metal and contain a movable date section, which was changed each day, but these are now printed automatically). These stamps use rather crude ink with a pigment contained in an oil- or water-based carrier. Official stamps are often carbon black in a glycol. It is necessary on occasions to establish whether a particular metal or rubber stamp has been used, and the principles concerning typewriters explained in Chapter 6 can be applied here. Variations in such stamps are found in the size of the mark, the style of the lettering, the relative position of words and figures, and the quality of the lines, especially at the edges. Even if the pattern of two or more stamps is exactly the same because of their production methods (rubber stamps are often cast; see the following section), wear and damage may produce some features that are found in the impressions of only one.

When any hand stamp is used, it will leave inked impressions of variable quality because the angle at which the paper is stamped, the amount of ink on the stamp, and the pressure exerted can all differ with each action. Care must therefore be exercised when comparing stamped impressions to ensure that this is allowed for.

Stamp marks can be transferred to other documents for fraudulent purposes, and this can be done in a variety of ways. Lithographic printing methods or others that produce a relief plate by photographic means are used, but more commonly, carbon black inks are "lifted" with wax paper and transferred to another document. This leaves a fainter impression, grey in color rather than black, and a thin layer of wax can be seen on the surface, often with indentations caused by the pressure needed to effect the transfer. However the stamped impression is transferred, there is normally adequate evidence to show that it is not genuine when it is examined under the microscope. In addition, because of the variability in genuinely made impressions, it is usually possible to identify the transferred or copied impression with its source. A comparison microscope can be used for this, or a transparency produced by photocopying or photographing the transfer can be overlaid on the suspected original to test the fit. The same method is suitable to demonstrate the findings to a court. Gas chromatography (see Chapter 7) can be used to confirm the presence of wax on the surface.

Rubber Stamps

Like metal stamps, those made of rubber or materials of similar composition are frequently used on documents and occasionally become the subject of an enquiry. They are related to letterpress printing in that they rely on an image raised from the background. They form two main classes, those that are mass produced and those that are made in ones or twos for a special purpose.

Date stamps made from a continuous strip of rubber are produced in large numbers, and each is not normally distinguishable from others of the same style. However, some faults may occur in manufacture, and damage may arise later so that the stamped impression is not perfect. These may provide evidence that a particular stamp was the one used to make a date on a document. The relative position of the components of the stamp is a variable factor. If the day, month, and year are not correctly positioned, the image will be misaligned, and a similar misalignment of the same date may be found on a questioned document.

Rubber stamps made for the use of an individual person or office are produced by first constructing a "chase" out of moveable type similar to that used in letterpress printing. This is pressed into thermosetting plastic material, in which it makes a depression from which the rubber stamp is molded. Alternatively, stamps are prepared from specially made depressed lettering from which the final product is taken. The rubber mat bearing the image is trimmed and mounted on a block to complete the hand stamp. It is possible that more than one stamp can be made from the matrix, so, although only one mold has been produced, it cannot be assumed that only one stamp exists. Hand stamps bearing facsimile signatures are also prepared by molding, so, again, more than one could be made.[17]

It follows that a stamped impression made from a rubber hand stamp will not necessarily be distinguishable from any other made by a different stamp from the same mold. However, a number of features that can make a rubber stamp unique can arise either in manufacture or in subsequent use. Those that are caused when the stamp is made include bubbles or unevenness in the surface, loose "fins" of rubber caused by defects in the molding, and the trimmed edges of the rubber base of the stamp. These can show in the impressions made on a document and provide proof of their origin. Similar evidence is provided by cuts, wear, and accumulation of dirt in crevices between the letters of the stamp. These are likely to occur differently on different stamps made from the same matrix.

To test whether a particular hand stamp has made an impression, it is necessary to make another with it. The impressions are compared by the use of either a comparison microscope or projector, or a photographic or photocopied transparency. It is rare to find that two impressions are identical; the variability of inking and in the pressure and angle introduced by the action of stamping will produce a lack of uniformity. In addition, there may be differences caused by wear or damage made to the stamp in the time between the making of the impressions. Also, the rubber may swell slightly after a period of use with inks, which it can absorb. Despite these differences, the presence of characteristic features can be detected.

Printing Sets

Another form of rubber stamp is provided by printing sets consisting of individual letters with a suitable block in which they can be mounted. These are made as toys or for office use but are sometimes used in documents involved in criminal offenses. It is then necessary to determine whether a specific set made the printed image.

Printing sets are made in large numbers, so the fact that the style matches is of little significance. There are sometimes small molding faults present in individual letters and, rarely, damage, but it is normally only when made-up blocks of type are found that a set can be identified with a particular printed impression.

The relative position of the individual characters is determined by the person making the composition and is subject to wide variability. Even if the characters are placed touching each other, the positions of the letters in their holders may give rise to variation. When spaces are left between words or when there are two or more lines of print present, their relative positions are significant because the chance that an identical setting could be achieved by coincidence or design is very small, or even negligible. If the edge of the block is reproduced with the impression, another variable parameter is provided.

Stamp-Pad Inks

Hand stamps are inked by a soft porous pad containing ink, kept separately or incorporated in the stamp itself. Comparison of the ink therefore provides another possible means of finding a link between a document and the instrument in question. Black stamp inks are generally made from carbon black and a suitable medium in which they are suspended, and afford few distinguishing features once they are dried on the paper. Other black inks and those in the variety of colors available are made of a mixture of dyes dissolved in a quick-drying solvent. They can be compared by means of the nondestructive and chromatographic tests described in Chapter 7.

It is sometimes necessary to compare the ink remaining on the rubber letters themselves. This must be done before test impressions are made with them; otherwise, there will be contamination with the ink used to make the impressions. The presence of ink on certain letters of a printing set but not on others may be an indication of what has been printed with the set. If the printing set or a date stamp has been acquired especially for use on the document in question, there may be ink only on those letters or figures required to make up the stamp printed on the document.

Dry Transfer Methods

Another method of putting lettering and other designs onto paper is by the use of dry transfer materials, sold under trademarks such as Letraset or Blick. The lettering, made of plastic material available in a number of colors, is printed on sheets of specially prepared paper and can be transferred to the document by placing the two in contact and exerting pressure on the back of the sheet of lettering with the point of a ballpoint pen.

In fraudulent and other criminal activity, dry transfer lettering provides a means to fabricate letter headings, serial numbers, and money amounts, as well as to write demand notes and other anonymous communications. The wide variety of styles available, mostly based on those in common use in the printing industry, include some that give the appearance of handwriting. In the investigation of documents using dry transfer lettering, it is possible to identify both the make of the material and also, if it is available, the actual sheet from which it came.

When dry transfer lettering is applied to paper, it is held there by adhesive that is incorporated in it. Under the microscope, it has a characteristic appearance and can be lifted from the surface with a sharp blade. The appearance of the surface of the material can be used to distinguish the product of one maker from another, but the far greater magnification provided by a scanning electron microscope enables further differentiation to be made. The analytical function of the same instrument can also be employed to advantage.

If the sheet from which the lettering was transferred is available, it can be compared in two ways. First, the missing letters can be related to those present on the document; the significance of an exact match between the two can be very important. If the only letters missing from the sheet correspond exactly with those on the document, the chances that this could be coincidental will depend on the number used. If this number is reasonably large, the chances will be negligible. If there are insufficient missing characters on the sheet, it could not have been used on its own.

Second, a more positive link can be established if the indentations on the backing sheet, caused by the pen used to transfer the character, exactly match those around the character on the document. In some cases, a part of a letter left behind on the sheet may be fitted to the rest of the character on the document.

Documents bearing dry transfer lettering should be treated with care. The characters may be removed if not handled carefully, and liquids such as those used to detect fingerprints on paper can loosen and dislodge them.

Miscellaneous Machine Printers

Various appliances are made that produce receipts, tickets, and other documents by different processes. They, or their products, occasionally are of interest to investigators, usually because it is necessary to link a machine with a printed entry. There is rarely any evidence in the more simple devices to prove that a particular appliance made the printing in question, but different styles of numerals may indicate the opposite. The same applies to the ink used for the printing, which is usually contained in ribbons or pads in the machine.

More complicated apparatuses can provide evidence to identify a printed entry with its source. Check writers, which are specially made to imprint sums of money on checks and other important documents, can develop faults that characterize a particular machine in a way similar to that of typewriters.[18]

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Incidental Marks and Other Scientific Examinations

9

Introduction

In other chapters, marks made by pens and other writing instruments, typewriters, and printing processes have been considered. These provide the information carried by the document, the reason for its existence. This chapter covers indented impressions, fingerprints, damage, and other marks that are incidental to the document's intended purpose but indicate its history. In addition, other matters of interest to the examiner of questioned documents not dealt with elsewhere are discussed. These are the examination of passports, envelopes suspected of having been opened and resealed, and the sequencing of crossed lines.

Indented Impressions

When writing is made on a piece of paper resting on others, it will leave impressions on the lower pieces. The most obvious site of these is on the next-to-top sheet of the writing pad when the top page is being used, but there are many other situations where impressions of writing are found on underlying pages.

The discovery of indented impressions can be of great significance. A letter written on a pad of writing paper may begin with the address of the writer, and the impressions of this will remain on the paper underneath. If that page is subsequently used to write an anonymous letter or a demand note, it will carry on it an indication of its origins. Similarly, pieces of paper can be associated if impressions of one are found on the other. Impressions of a demand note may be detected on the pad on which it was written, thus providing proof of its source.

A variety of other information can be obtained from indented impressions. Pages next to those torn out of a diary or address book can reveal what has been removed; in some cases, the entries removed are rewritten to leave out an incriminating line. The order in which writings on different pages were made can be established, showing perhaps that all were not made in the correct order; in other cases, the relative alignment of indentations of certain particulars may show that different parts of a document were or were not written at one time.

Detection of Indentation Impressions

Oblique Lighting

The indentations produced by writing on an overlying page can often be clearly seen; for a long time, the only techniques used to detect them depended on methods to enhance their visibility. Despite a number of suggested improvements, the best results by visual examination are obtained by the use of oblique lighting. Illumination from a point source at a shallow angle will produce shadows in the depressions and render them visible. In most cases, some of the impressions are too weak to be read clearly, and some patience is required before all that can be read are identified. The light source is moved so that the angle of incidence is changed to show different parts of the indentations more clearly. The document can be imaged under the best lighting conditions to provide a record of the indentations, but because all the variations in the lighting conditions cannot be used in one exposure, a single image will not reproduce all that can be observed by actual examination. A curious feature of indentations viewed under oblique lighting conditions is that they sometimes appear in the image to be raised rather than depressed. This is an optical illusion, but can be confusing to the layman in court. Turning the image through 180° eliminates this optical illusion.

Shading

Other methods suggested to improve the visibility of indented impressions have not been very successful, and some have the disadvantage that the document is damaged by them. One such method is to rub the surface lightly with a soft pencil, so that only the depressions are not blackened and therefore show up against the surrounding areas. This is reasonably beneficial for deep impressions, which will in any case be revealed by oblique lighting, but will not detect shallow ones. The method is likely to render other methods less effective and should not be used.

Electrostatic Detection

An entirely different technique, which does not rely on a visual examination and does not damage the document, is the electrostatic method of detection. Impressions made on paper affect its dielectric properties, so an electric charge applied to the surface produces a potential difference where impressions are present from that of the surrounding area. Why this occurs is not clear, but the effect is of considerable value to the document examiner and is exploited by the use of an apparatus designed especially for the purpose.

The Electrostatic Detection Apparatus (ESDA) made by Foster and Freeman Ltd. (Evesham, Worcestershire, U.K.) comprises a porous flat brass bed from below which the air is evacuated by a vacuum pump, a holder of a reel of thin transparent plastic film, and a thin wire in a suitable enclosure that can be charged to about 8 kilovolts. To use the apparatus, the document is placed on the bed, covered with plastic film, and the vacuum is applied. This causes the film and the document under it to be sucked tightly down on the bed. A charge is then applied by passing the highly charged wire, called a corona discharge unit, several times just above the surface of the film. This produces on the film, referred to as imaging film, an electrostatic charge whose potentials are dependent on the dielectric properties of the paper immediately below it. Because these are different where there are indented impressions, there is a difference of potential on the imaging film corresponding to the position of the impressions.

The difference in potential between the sites of the impressions is then detected by the application of photocopy toner powder to the surface in one of two ways or by a combination of both. Included in the original apparatus is a pump, which forces a cloud of toner powder from a reservoir through a nozzle, charged at the polarity opposite to that of the surface of the imaging film, which is fixed into a plastic hood. The hood is placed on the flatbed so that it covers the document and film. When the pump is switched on, the toner powder cloud is mainly attracted to the impressions, as these are the areas of greatest opposite charge. The second way of applying the toner is to pour a developer consisting of toner and glass beads over the surface. The bed is tilted, allowing the developer mixture to cascade across the whole area of the plastic covered document. The greater potential at the site of the impressions attracts the toner away from the glass beads (Figure 9.1). Other ways of applying the powder have been developed recently but the principle is still the same.

The methods of detection of the differences of potential leave black toner adhering to the surface of the film exactly on the site of the impressions. Most impressions will appear as a black or grey image contrasting with the general light grey color of the rest of the surface where some toner has been evenly deposited. This enables many of the impressions to be clearly identified and others to be read with a varying degree of ease, depending on the contrast between the image and the background. Generally, the deeper the indentations, the blacker the image, but very deep impressions will often be seen in reverse, appearing white against the grey background. The electrostatic method is very sensitive, often detecting impressions too faint to be seen (see Figures 9.2 and 9.3).

The image produced on the imaging film can be preserved by covering the surface with a sheet of adhesive transparent plastic of the type used as a protective cover for books and other documents. The film, together with the

Figure 9.1 The electrostatic detection apparatus (ESDA) made by Foster and Freeman Ltd.

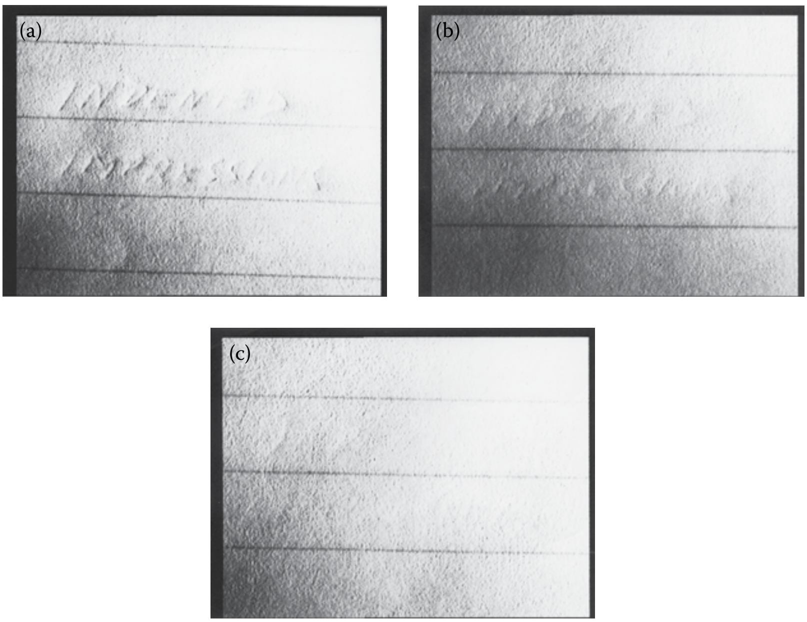

Figure 9.2 Three pieces of paper, which were below another on which the words "INDENTED IMPRESSIONS" were written, photographed with the use of oblique light. Page (a) was immediately below the first piece of paper, while (b) and (c) were two and three sheets below respectively.

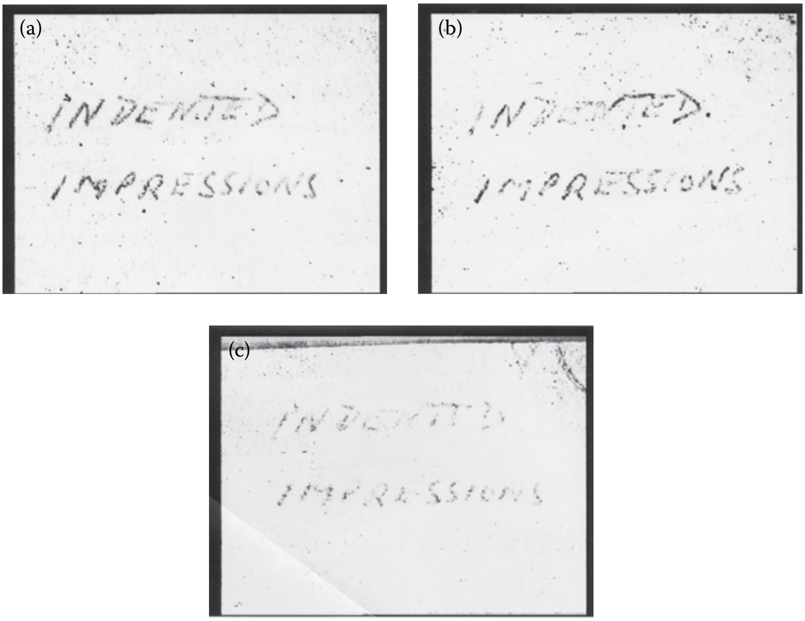

Figure 9.3 The result of the examination by ESDA of the same pieces of paper (shown in Figure 9.2). Note that the impressions are easily readable on all three pieces of paper. In contrast, oblique lighting detects impressions only on the first two pieces.

image on it, is lifted by the adhesive sheet and forms a transparency, which can be trimmed to make a document on which the indented impressions are permanently recorded. Although much can be read while the image is still on the apparatus, more can often be seen on the resultant lamination of imaging film and adhesive plastic sheet. The transparency, or "lift," which has something of the appearance of a photographic negative (although there is no connection between the two), can be used as an exhibit in later litigation. The backing sheet of the adhesive transparent plastic is normally placed behind the laminate to make its details easier to observe.

The transparency can also be used to overlay writing suspected of having caused the impressions; if the writing is indeed the source, there will be a perfect fit. The relative alignment of the impressions can also be similarly tested against that of the writing. The image of the impressions is often sufficiently clear to enable a comparison of the handwriting to be made with that of a suspect. In one case, the writing of a threatening letter did not match that of the suspect, but the impressions of the same wording found on the letter did. On the previous page, the suspect had written a draft for an accomplice to copy.

The electrostatic method is very sensitive, but it is not successful in certain situations. A line of writing, although clearly indented into the paper, will not react in the same way as other indentations, but will usually appear in reverse, as a white line on the grey background. This is an advantage, because writing on the paper on which impressions are found could otherwise be confusing and make the impressions largely indecipherable. As it is, there is sometimes a problem when impressions of two or more pages are found and their superimposition causes difficulties in interpretation.

Electrostatically produced images can be obtained from both sides of a piece of paper, indicating that it is not only the depressions that are detected; it is sometimes found that the back of a page will provide a better result than the front. It appears that dryness of the ambient conditions and those in the document are not conducive to good performance, and improvements in weak images can be made if the paper, the toner beads, or the room are humidified.

Although it is not always clear why the technique is on some occasions less successful than on others, certain findings indicate that it is likely that what is detected is caused by moving pressure applied to a paper surface in contact with another piece of paper. An exhausted ballpoint pen, for instance, will make indentations, but they will not be easily detected by the electrostatic detection apparatus, nor will impressions made on paper by writing over plastic where the indentations are made by plastic-to-paper contact. Although what is detected will remain for years, the method will not work once the document has been treated with a solvent. This makes it important to test for indented impressions before any chemical treatment for fingerprints is carried out. Similarly, wiping the surface of the paper with a piece of cloth will remove what is detected by the method.

Indented impressions of typewritings are occasionally found on documents that have been used as a backing between the paper being typed and the platen of the machine. These indentations are best detected by oblique lighting; electrostatic detection is rarely effective for this.

Secondary Impressions

When a piece of paper bearing writing that is so heavy as to be embossed on the reverse is placed on another sheet of paper and pressure is applied, from the weight of other pieces of paper resting on it, for instance, the protruding embossments can produce impressions that are detectable by ESDA on the page below. Some movement is required between the two sheets of paper so that there is paper-to-paper contact abrading the surface at the position of the embossments. The methods then detect what appear to be impressions made at the time of writing but are caused by preexisting deep impressions already on the page above. These are called secondary impressions.

Generally, they are faint, diffuse, and not clearly readable but can be precisely aligned with the original writing if this is available. Primary impressions may not be so closely aligned if the top and underlying pages change their relative position during writing. Secondary impressions sometimes show a greater width in one direction due to restricted movement between the embossed page and that below it. However, it is not always possible to distinguish between secondary impressions and primary impressions made through several sheets of paper.

In a similar way, the physical state of a piece of paper, its edges, and any folds or tears present can be detected by electrostatically testing the immediately underlying page, provided that the same conditions of pressure and movement have applied.

Fingerprints and DNA on Documents

Apart from impressions, the electrostatic detection apparatus will reveal other marks on paper. Fingerprints can be found if they are fresh, but it appears that as they dry out, they no longer produce any difference in the dielectric properties of the paper. Shoemarks caused either by the transfer of dust, moisture, or pressure can also be detected by this technique.

It is not within the purpose of this volume to describe the comparison of fingerprints, but it is common knowledge that a mark sufficiently clear and adequate in size can be identified with its source, a finger, thumb, or palm of a particular person. It is important to note, however, that fingerprints can be found on paper, indicating with certainty that it has been handled by an identifiable individual.

A number of methods are available for the detection of fingermarks on documents; some are destructive, so that any evidence from the document is lost, and others are less so. Lighting techniques can be applied to a document before ESDA examination without destroying information, but dusting and chemical techniques are best applied after the examination. If the document is handled carefully by the edges or by parts less likely to contain fingerprints (e.g., the top of the document), then fingerprints can be developed subsequently. Operational reasons may give priority either to fingerprint development or document examination, but should seek to maximize the information to be gained from the document. In any case, where both disciplines are involved, there should be cooperation between the experts.

Similarly, the investigating officer may wish to investigate whether DNA can be found on a document. This is usually in the form of "touch" DNA—cells left behind when a document is handled—but could also take the form of saliva on lick-seal envelopes or gummed stamps (less common these days). The techniques for retrieval of DNA from paper involve swabbing the surface with a damp cotton bud, particularly if there is an obvious fingermark. This needs to be done before indented impression examination, as the ESDA machine and its component parts cannot be made "DNA-clean" and therefore contamination with what has gone before is a real possibility. While introduction of water to the surface may damage indented impressions (although not necessarily—the paper is not left noticeably wet) swabs would usually be taken from areas most likely to have been held—for instance, the lower corners of the document. These areas are less likely to contain indented impressions, so it may be that, through discussion between experts and the investigator, both examinations can be done.

Damage to Documents

Folds and Creases

It is often necessary to fold a piece of paper to make it easy to handle or to place it in an envelope. Although such minor damage does not have much significance in most documents, there are occasions on which invaluable evidence can be obtained from it. The effect of a pen moving over a fold or crease is normally noticeable when examined under a microscope. The act of folding a piece of paper breaks the top calendered surface and exposes fibers with different absorbent properties. As the pen passes over the damaged area, there is a tendency for more ink to be picked up by the fibers. This is accentuated by the ridge caused by the fold, which provides a greater resistance to the pen than does flat paper. The resultant extra ink at the crossing point contrasts with an even coating of that of the rest of the line. When the fold is made after the ink line, there is no reason for extra ink to be found, and although there will be some changes in appearance caused by the breaking of the surface at the crossing point, they will not show the same effects.

The most important reason for determining whether the fold has been made before the writing line or after it is to show the order in which two writings have been made. It may be important to establish when a fold was made in relation to an ink line, but it is more likely that the relative time of writing of two entries, each crossing the same fold, will be of significance. Other forms of recording information, such as typewriting, pencil lines, and rubber stamps, will also produce different effects when made over folds or creases, and these can also be used to discover in what order they were made.

Creased carbon paper has provided evidence to show that two carbon copies, each containing different information and with inadequate typewriting for proof of a common source, had been made using the same piece of carbon paper. This had been irregularly creased during its previous use, and the pressure exerted by the machine on the combination of paper and carbon resulted in the pattern of the creases being reproduced on both copies. Such an examination is not a routine method in document examination, but it illustrates the occasional unusual finding that can be of great significance.

Staples and Paper clips

Although staples are commonly used to keep a bundle of documents together, their presence is rarely of any significance in the investigation of crime or in any other concern of the document examiner. Sometimes, however, it is important to know whether two or more documents have been stapled together, or how many times they have been separated.

The commonly used staple is made of soft metal and is shaped like a rectangle with one side missing. When it is forced into the paper by the stapler, its parallel sides are bent round and it makes either two holes, or, if it is inserted with greater force, two further marks between the two holes where the bent ends touch the paper. It is possible with care to remove the staple and replace it without leaving evidence that this has been done, but on other occasions, the staple will be distorted and therefore show evidence of tampering.

When a staple is inserted, the position chosen will vary within certain limits. Although the general position, usually near the top-right or top-left corner, will be common to many documents, the exact place and angle of the staple will show a considerable variation in hand-stapled documents. This means that once the staple has been removed, the position of the two (or four) holes it leaves will not be the same in relation to the edges of the paper as those of another bundle of papers except by a most unlikely coincidence. If the bundle has been separated and restapled, leaving further holes, the chances of coincidental match are even smaller. Strong evidence that two or more documents have been stapled together at one or more times is therefore provided. When staple marks are examined, some account must be taken of the fact that movement of the pages can cause the holes to enlarge. This in itself can provide extra evidence to link two documents if both have similarly wider holes. In other cases, the documents may have been torn away, leaving a tear between two holes.

Examination of staple marks can show whether photocopies originated from a particular bundle. The staple or its marks will normally show on the copy, or the turned-over corners will be apparent if a bundle has not been separated. The period during which the copies were made may also be ascertained by the presence or absence of copied staples or holes.

The value of occasional or nonroutine observations in document examination is illustrated by a case where a woman was attacked and her handbag taken. It had been the practice of the woman's employer to staple all the notes into wages packets so that they could be checked before the staple was removed. A pair of staple holes on a pound note found on the suspect exactly matched the holes on the woman's wages packet made when the note was put into it. Comparison with other wages packets showed that there was considerable variation in the position of the staples and that the match was therefore highly significant.

Paper clips leave marks that are obviously less visible than those left by staples, but the impressions that can be found slightly indented into the paper can also provide evidence to link two documents. There is less variation possible in the positions in which a paper clip may be placed, but the chances of an exact match occurring by coincidence are still low.

With both paper clip and staple mark evidence, complications can occur when other staples and clips are used after the investigation or trial has begun. These may cause confusion, and it is best to avoid further damage to any document under investigation. There is a need to identify a particular document with a label, but it is important to consider that the act of labeling may damage significant evidence. Labels stuck onto documents also may destroy important evidence.

Deliberate Damage

In some respects, the marks found on documents and described above represent forms of damage, but in certain cases, documents are deliberately damaged or destroyed to avoid the information they contain being discovered. In other cases, accidental damage occurs.

It is one of the functions of a document examiner to discover what has been lost in such cases. If the page in question has been completely destroyed or lost, the only approach is to examine pages that were previously underlying or adjacent in the hope that indented impressions or offset marks may be found. In instances where the document is completely changed by the action of fire or moisture—charring, for example—it may be possible to discover what was present before the damage was done.

Charred Documents

If a piece of paper is completely burned, all the organic material is destroyed, and only inorganic ash remains. The appearance of this will depend on its chemical composition, which in turn will depend on the filler in the paper and also on the inorganic components of any ink that was present. Ash from inks is more likely to be visible if it derives from printing rather than writing or typewriting because printing inks have a much higher proportion of inorganic compounds.

Little can be done with documents that are burned down to ash, because they disintegrate almost immediately. Nevertheless, one method suggested for the determination of what was present on incompletely burned or charred paper involves the further charring of what is found until it consists entirely of ash.[1]

More usually, documents are examined when they have not been completely burnt but are merely charred, and, although brittle, can be moved with care. In this condition, writing, typewriting, or printing contrasts with the background in a number of ways, depending on the composition of both the paper and the ink. The information from the document can then be observed. Various methods have been described to improve the contrast between the ink and paper, but most tend not to improve the clarity, or even make it worse. They may also damage or break up the brittle, charred fragments. Examination or imaging under infrared radiation can, however, be helpful and is nondestructive. This may appear surprising because carbon absorbs infrared as well as all other wavelengths, and the black fragments seem to contain much carbon. In practice, however, the contrast is often improved, presumably because the inks absorb infrared radiation, while the charred paper is black because of partly converted resinous material rather than because it has degraded to elemental carbon.

Whether or not imaging can enhance the contrast between the writing or printing and the background, it is of great value in recording what is visible. Charred documents can easily disintegrate, so it is important for a permanent record to be made.

The preservation of charred paper can be aided by carefully dropping a solution of plastic material on it so that it is absorbed and therefore permanently strengthened when the solvent has evaporated, but this causes the information it contains to be made less clear.

Matted Documents

Documents soaked in water are found on unidentified bodies, often in a state of decomposition, or may be recovered from the mouth of a suspect who has attempted to destroy it by eating it. In both cases, the effect of the moisture is to cause the paper either to adhere to itself in a screwed-up mass or for separate pages to become matted together. The penetration of the water may also cause the ink to run.

To determine what was written on the document, it is necessary to separate those areas that are adhering. Careful prizing apart of the dried material can be successful (the conglomerated mass is usually dry when it is received), or it can be moistened first and then separated and straightened. Generally, separating documents when they are still damp is easier and less likely to damage them than attempting to separate them when they are completely dry. Examination under conditions that excite infrared or visible luminescence may enable washed-out entries to be identified from the insoluble traces that remain.

Freeze-drying has been reported as a successful method of separation. The dried mass of documents is soaked in water and then placed in the chamber of a freeze-drier. This results in the water being removed and the substances holding the paper together being broken down so that the pages can be easily separated.

Shredded Documents

Attempts may be made to destroy a document through shredding. If the shredder is of the longitudinal cut variety then it is a relatively straight forward process to piece the shredded documents back together and thus recover the evidence. The examination can be a time-consuming one, depending on the size of the shredded fragments and the amount of material recovered. When collecting shredded paper from a bin or shredding machine, the investigator should preserve the bundle of shredded material in the state it was found as shreds from the same document are likely to be found in the same layer. Modern security devices will often cross-shred, resulting in smaller pieces of document and making the recovery of complete documents extremely difficult.

Initial sorting of the shreds can be done according to the color or type of paper they came from. By viewing the shreds using a UV light white paper may be further categorized. Blank or near blank shreds can be discarded. Once the initial sort is completed then it is simply a matter of laying the pieces of paper out on a semi-tacky adhesive surface and moving them around until matches can be found. Completed documents can be preserved by mounting them on low-tack paper or on sticky-back transparencies. If other examinations are required, such as DNA or fingerprints then these are best done first as the examination of shredded documents requires the shreds to be handled. There have been some attempts to piece documents together electronically and thus avoid excessive handling, but this is still a very time-consuming task.

Erasures and Obliterations

In Chapter 7, methods of erasure and obliteration and their detection by examination of inks and traces of inks were discussed. The surface of paper is affected in the process of erasure, either chemical or mechanical, and it is often of importance to show that such action has taken place. Other marks or stains that have been made accidentally or deliberately are found in documents, and these may have some importance in an investigation.

A liquid applied to the surface of a document will leave a mark at the limits of its extent. This may not be visible in normal light but will show when the document is examined under ultraviolet or conditions that produce infrared luminescence. A document completely dipped in a solvent may not show this effect, but the paper may have an irregular or crinkled effect. Tests for the chloride ion, a product of the bleaching agent, can be made, but are rarely necessary. Effects of solvents are also found when security papers are altered; these sometimes contain special materials that stain the paper when it is treated with a liquid. Printed security backgrounds also react to such treatment.

Some security papers are made that react to mechanical action by producing staining, but most altered documents do not. Examination for areas where erasure may have taken place is best made by the use of oblique light. This shows the loose fibers that result from the breaking down of the surface coating of the paper and the general roughness of the abraded surface. Soft x-rays or a source of beta radiation, more usually used on documents to record watermarks, will also detect areas where paper has been removed, along with the ink that has been erased.

Writing made with pencil or erasable ballpoint ink can be removed by an eraser without damage to the paper surface, and if traces of the writing material or indentations cannot be seen, little evidence is left. The action of the eraser, however, leaves traces of rubber or other material on the surface that, although too small to be seen, can be detected with specially stained lycopodium powder. This is composed of very small spores colored to make them clearly visible. When placed on the erased surface, the powder adheres to the affected surface. The action of gently shaking or tapping the document causes the powder not adhering to the surface to fall away and that adhering to remain, thus demonstrating the area over which the eraser has been used. This technique may reveal other marks left on the surface of the document, not just erasure. The powder can be brushed off, leaving the document unaffected.[2–4]

Altered Envelopes

One of the special problems encountered in the examination of questioned documents is the determination of whether an envelope has been opened and resealed. There are a number of reasons for this examination. The recipient of a letter may claim that money or some valuable document was not present when it was opened, a sealed safe deposit envelope may have been opened, or the sealed packet containing a sample of blood taken for alcohol determination may have been opened to replace the blood before analysis. In nearly every such case, the examiner is given an opened envelope and needs to determine from it whether there is evidence of a previous opening and reclosing of the envelope. In some cases, the task is made easier by security measures adopted when the envelope was first sealed. These can include the presence of sealing wax or adhesive tape, or signatures may have been made across the edges of the flaps.

The methods employed to open an envelope with a view to sealing it again are to attack one of the flaps by pulling it gently off, possibly after moistening the glue with water or steam, or to make a clean cut along one edge. To close the opened envelope, an attempt may be made to use the original glue or, more often, to add extra adhesive; in the case of a cut edge, a very thin line of glue is added to the insides of the cut edges. In some cases, an unsuccessful attempt may be made at one site before the task is performed on another.

The detection of such action involves a number of examinations, beginning with those that do not further damage the envelope and continuing to those that require it to be taken apart.

When a flap is opened by moistening with water or steam, the surface becomes crinkled, and the action of tearing it away from the main body of the envelope may cause it to become torn. A preliminary examination, therefore, is made to establish whether the flaps at the top and bottom and on the sides are smooth and undamaged. The edges should be gently raised to look for extra glue, which may extend beyond the area covered by the flaps. In an unaltered envelope, there will be a small gap between the edge of the flaps and the glue, so any adhesive occurring right up to the edge is indicative of abnormality.

Extra glue under the flap can be detected by using a micrometer to measure the thickness of the appropriate areas and compare them with that of an unaltered similar envelope. A better method to detect extra adhesive is to use soft x-rays. The greater mass of the glue absorbs more x-rays than do the surrounding areas and shows as a lighter area on a negative image. In contrast to glue put on the envelope in manufacture, which is in evenly shaped approximately rectangular areas, added adhesive is irregularly applied with no consistent form.

Signatures written over sealed flaps or seams of an envelope can be reconstructed when the envelope is resealed, but it is not easy to put the flaps back so that both parts of the signature are exactly in alignment. Instead, parts of the writing line may appear under the flap or, if the replacement of the flap is out of line in a horizontal direction, two sections of a continuous line will not connect. Care has to be taken to avoid erroneous conclusions; it is sometimes possible for a pen to slip under a flap when the signature is first made, and the normal action of a pen moving from a higher to a lower surface results in a small gap in the writing line by the edge.

Adhesive tape provides an effective method of sealing an envelope and cannot easily be removed without taking off the surface layer of the paper. Replacement with another piece of tape may disguise the damaged surface, but the appearance will not be exactly the same. Careful observation of the surface through the tape will show that the surface has been affected. A signature under the original tape may be partly or wholly removed with the tape and will be almost impossible to replace; its absence will therefore provide clear evidence of tampering.

If a nondestructive examination does not afford conclusive proof of resealing, the envelope has to be taken apart. This is best done by cutting the sides where there is no likelihood of destroying any evidence. The inside surface can be examined for excess glue or any resealing of cut edges. The last operation is to pull the flaps or seams gently apart to discover any extra adhesive or any signs of a previous opening. If an envelope has been sealed by the use of only part of the adhesive, it is possible to use the rest to reseal it. In most cases, however, extra glue is needed.

The opening of the flap or seam may also result in tears to the inner surface of the paper; those made at the first opening can be discovered under extra glue. When latex rubber seals are pulled apart, strips of adhesive are produced that break and collapse, leaving coils on the surface. These provide evidence of previous opening.

The Examination of Adhesives

Although the presence of extra adhesive, detected by soft x-rays or by visual examination on an opened flap, is in itself of significance and may require no further confirmation, chemical analysis of the material may be appropriate in order to show that there are two different materials present. On the small amounts of glue that can be removed for testing, only a limited examination can be made, sufficient to identify its type rather than the manufacturer or batch.

There are several main types of adhesive provided for office and domestic use: dextrin or starch-based products; protein glues; latex adhesives; and synthetic materials such as solvent-based plastic compounds, epoxy resins, and cyanoacrylic resins. The removal of a few particles of the dried adhesive from the surface and their examination under a low-powered microscope can give an indication of its type. For instance, a latex glue will be pliable, and one based on polyvinyl chloride will appear shiny, while others may crumble easily or remain difficult to break up. Although separate simple tests can be performed to identify the main types of adhesive, pyrolysis mass spectroscopy, which breaks the sample down into small molecular fragments, the combinations of which are characteristic of the adhesive type, provides a single method by which each can be identified. As well as indicating the presence of more than one adhesive, the method can be used to compare the added material with any source that may be found in the possession of the suspect.

The Examination of Passports

Passport examination presents the document examiner with a specific range of problems, some directly involving the techniques employed on other documents and described elsewhere, but others found only with passports or similar articles such as identity cards or drivers' licenses. The task of the examiner is to determine the authenticity and integrity of the document by testing it for differences from the genuine product and detecting alterations and erasures. Passports and identity documents are now very sophisticated; they incorporate multiple security devices such as holograms, fugitive inks, biographical data, machine-readable strips, and so forth. Because of this, the examination of passports at borders is a complete topic on its own and is outside the scope of this book. Only an overview of the issues involved is provided below.

There are essentially three methods of falsifying passports, causing them to give information that is not appropriate to their holders. These are:

1. The complete counterfeiting of a genuine passport.
2. Making an alteration to the written or printed information.
3. Substituting a photograph or a page of the original passport.

The discovery of the evidence for the first two methods is dealt with elsewhere. Counterfeiting requires a copying of the paper and the printing and security features of the original, and its detection depends on comparing genuine documents with those suspected of being spurious. Without adequate authentic examples to compare, it is impossible to be sure that a passport is a counterfeit. The quality of some genuine passports is not high, and these can be wrongly suspected to be falsely fabricated.

Alterations to specific written or printed entries in passports are made for a variety of reasons. Names, dates of birth, and other entries are changed by erasure and overwriting, or by simply overwriting or adding extra letters or words. Entry or exit stamps are also altered, and unwanted endorsements written or stamped in the passport are chemically or mechanically removed. Modern passports contain many security features that are designed to prevent alteration or make the attempt obvious. However alterations can still be made by the skilled counterfeiter that will go undetected on a casual inspection. The techniques for the detection of such alterations are described in Chapter 7.

The third method of falsification, by substitution, requires different techniques of examination. A stolen passport is likely to be fraudulently used by another person different in appearance, so it is necessary to change the photograph by removing the original and replacing it with another. In most modern passports, the photograph is digitized and etched into the paper and plastic films so that any substitution of the image is almost impossible. If a page bears an unwanted entry or image, it may be possible to change the page from another passport. In this case, the inconsistency between pages will be apparent and can be an indication of substitution. Substitution is still very difficult to do successfully, as it requires the dismantling and reconstitution of the document, but it may be sufficient to pass a casual inspection without raising suspicion. Page substitution is more easily detected in the examiner's laboratory, but the earlier, more cursory examination at a point of entry may be inadequate to discover evidence of substitution.

The techniques of detection of substituted pages are those of observation. Examination under relatively low magnification can detect the evidence of tampering with security devices such as embossed stamps and signatures. Substituted pages are discovered by examination of the binding of the passport and by comparison of the paper. Page numbers are sometimes altered when the appropriately numbered pages are unavailable. Images that should occur on every page of the passport may be different on the substituted pages. As with complete counterfeits, the key to this examination is knowing what the original should look like, so a good source of control documents is essential.

Crossed Lines and Sequencing of Writings

The sequencing of two lines that cross, or the determination of which line was made first, is of considerable value in certain cases. A paragraph or sentence written immediately above a signature may be in dispute, the signatory claiming that it was not present when he or she signed the document. If part of the writing of the disputed passage crosses the signature and it can be established which of the two was present on the paper before the other, the dispute can be settled.

The problem, however, is not as easily solved as it might appear to be. The concept of a layer of ink over another is easy to imagine, but is not found in practice. Instead of forming a film, like a paint layer, ink is absorbed into the paper. A subsequent line drawn across it fills un-inked spaces and mingles with the already deposited ink so that direct or magnified observation cannot distinguish the first applied ink from the later one. A darker-colored line or one with a higher proportion of ink will appear to be on top of a lighter-colored line or a thinner ink whether it is or not. This illusion can be misleading if it is not recognized as such.

Other sequencing problems occur with lines made of a variety of materials, different writing instruments and their inks, typewriting with various types of ribbon, outputs from different computer printers, and marks made by rubber stamps.

Liquid Ink Sequencing

Inks based on aqueous or other mobile solvents soak into the surface of normal paper entirely, so nothing can be determined from the apparent presence of a top layer. The situation is like that of a twice-dyed piece of cloth; the darker color will dominate to the exclusion of the lighter. Evidence of the order of the crossing strokes can be provided by the effect of one line on another. In the now largely obsolete iron-based inks, the paper in the ink line was affected so that it would take up the ink of the second line and draw some of it away from the crossing by capillary action. This gave a darker appearance to the line along a distance of around 1 millimeter on either side of the crossing, indicating that the partly darkened line was made first.

This phenomenon is now hardly ever found, but if two different inks cross, the second may remove a trace of the first and carry it a short way down its length. Because such a transfer involves only a very small quantity of ink or a component of it, detection is possible usually only when the transferred constituent luminesces or fluoresces strongly and differently from the overwritten ink.

Ballpoint Inks

Writing with ballpoint pens requires heavier pressure than that needed for liquid ink pens. The impressions of grooves that are formed by this pressure can be exploited when considering which of two crossing lines was made first. A pen crossing a groove will be influenced to some extent by it, and this may be detectable. However, heavy pressure of the pen will distort the groove as it crosses it, and, if sufficient, will flatten the paper so that there is no difference in the level of the surface at the crossing.

If a more lightly written stroke crosses a depression, the evenness of the ink line will be affected. A greater quantity of ink will be deposited on the further or uphill side of the groove, with some loss on the side where the paper surface falls into the depression. This effect can sometimes be seen as a narrowing and widening of the ink line, in the shape of an hourglass, as it crosses a previously made stroke. These features are observed under magnification of around 10–30× using a suitable incident light microscope.

When two inks are similar in color, or if the same ink has been used for both lines, these effects are difficult or impossible to detect. Infrared absorption or luminescence may be used to determine the sequence of the writing of two lines if the inks react differently in these conditions. The unevenness of the line at the crossing point may be discovered only when it or the other ink fluoresces or if the crossing is examined in conditions under which the other ink is not visible. In some circumstances, quenching effects can make the fluorescing line appear to narrow, and this can be misinterpreted as evidence that this line is on top.

Writing on one side of a page can leave impressions deep enough to affect the surface on the other side. Raised lines (embossments) caused by depressions on the reverse may influence a line written across them. Provided that the pressure exerted by the pen making the line is not too great to flatten the ridge, a larger deposit of ink will appear on the rising side and a correspondingly smaller amount will be present on the falling side. These effects can be found at a number of points where the writing lines from either side of the paper cross. They may be of value if the order of writing of the two sides is in dispute or if the relative ages of two pieces of writing on one side can be deduced from writing on the reverse.

Depressions made with ballpoint pens can affect writing lines made later with liquid inks, but the opposite order of strokes will rarely leave evidence. A liquid ink pen usually leaves the surface of the paper virtually unchanged and flat, so no effects on the shape of the surface will occur.

Determination of the sequence of writings on both sides of a sheet of paper, including cases where the possibility of a later addition to an entry is to be investigated, can be achieved using ESDA, where intersections of writings and embossments (indentations on one side appearing on the other side) can produce conclusive evidence. This is considered later in this chapter.

Various other methods to determine the sequence of crossing ballpoint ink lines have been suggested but are not widely used. One of these involves the use of a shiny coated paper, which is pressed onto the crossing with a hot iron so that a partial image of the ink lines is transferred to the paper. This accentuates the edges of the lines, so they appear as narrow parallel "tramlines." Continuous tramlines crossing broken ones from the other line provide an indication that the stroke that made their image was made last, but in some circumstances, misleading features can arise.[5]

Other methods have been described that use a high-powered microscope and a light source focused downward onto the crossing point. These methods rely on a difference in the reflected light from the surface, a continuous line indicating the upper stroke, and the different broken reflection of the lower one. Raman spectroscopy has also been used to sequence inks.

Ballpoint and liquid ink lines written on glossy paper present few problems of sequencing. Because they are not absorbed into the paper but dry on the surface, they are affected by subsequent lines that cross them. There is a tendency for the ink to concentrate at the edges of the line, rather like squash lines in letterpress printing (Chapter 8); the last line made is indicated by unbroken parallel edges at the crossing contrasting with the edges made first, which are broken.

Offset Marks

When two pieces of paper are pressed together, marks such as writing and printing may be transferred from one to another. The effect is dependent on the dryness of the materials in contact; moist inks are obviously more likely to transfer than those that have completely dried out. The required pressure between the two pages is often provided by a writing instrument. Writing made on one side of a page can cause writing on the back or on a second page to be transferred to the surface with which it is in contact. Such offset marks indicate the order in which writings are made because the ink transferred by the pressure of the pen must have been present first. Such transfers will occur only when inks are freshly applied. Ballpoint inks dry within minutes, so if transfers are found, this can be used to show that entries on several pages of a diary were made at one time even when they are claimed to have been written over a longer period.

As well as writing made with ballpoint ink or pencil, materials such as printing ink or dirt from the surface on which the paper is resting can be transferred. Off-set marks may be visible to the naked eye, but further information may be revealed using specialized lighting techniques, discussed elsewhere (Chapter 7).

Pencil Lines

The small amount of material deposited by a "lead" pencil on paper and the incomplete covering of the whole of the area it marks make any line crossing of two such pencil lines, or a pencil line and either liquid or ballpoint ink, difficult to sequence. It is in fact rarely of any interest to an investigator or to a court; entries of any significance are infrequently made in pencil.

Wax Crayon Lines

Wax crayon lines are made of thicker deposits of material, and evidence as to whether or not they were made before other lines can be found by using a scanning electron microscope. This instrument will display certain materials at high magnifications so that they can be seen resting on the paper surface. It will not, however, show others (liquid writing ink, for instance), because they are in, not on, the paper.

Wax crayon appears as a granular mass and ballpoint ink as having a paste-like consistency. Complications are caused by uneven deposits, but a line made by a pen crossing a wax crayon line will smooth out the granular surface whether or not it deposits ink. A ballpoint crossing over a wax line or the same lines made in the reverse order can be sequenced by observation of the relative position of the two materials. This is not always entirely clear, and some experience is needed to recognize the appearance of the images of different media.

Sequencing of Indented Impressions and Writings

Indented impressions detected by ESDA produce black images on the transparency (Figure 9.3), but dry ink writings generally show up as white lines (clear on the transparency). Where the images intersect, the order in which they were made can sometimes be determined (Figure 9.4).

However, the interpretation of the ESDA images requires care. Tests have shown that when ink writing came after the impressions on the page, the image of the ink line appears continuously white over the black image of the impressions at the intersection points. When impressions are created after ink writing, it has been found that a proportion of the intersections appear dark (that is, when the white lines of the image of the ink lines are broken by the black impressions image), but the rest appear white. The proportion of dark to white impressions can be quite low for ballpoint writings, but much higher for water-based inks such as fiber-tipped or rollerball pen inks. Therefore, when one or very few intersections occur, the only observation that can lead to a determination of sequence is that of a black intersection. This provides

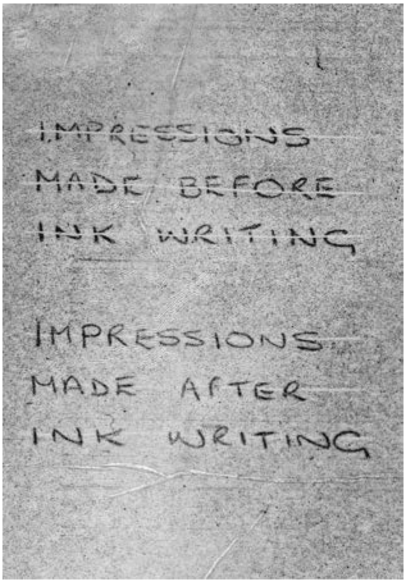

Figure 9.4 Impressions of words written both before and after horizontal lines written with a rollerball pen, detected by ESDA. Note that the impressions, shown in black, are broken by the white lines of the ink when they were made before the lines, but not when they were made after the lines.

strong evidence of impressions coming after ink. With one or very few white impressions and none black, great caution must be exercised or no conclusion can be given because white intersections can occur with both sequences. However, when a large number of white intersections appear together on one page, typically 10 or more with ballpoint ink, a qualified conclusion that the ink came after the impression is appropriate. Normally, there are many intersection points between the ink lines and impressions, and a qualified conclusion that ink writing came after impressions for observations of all white crossings and a certain conclusion that the impressions came after the ink for observations of black intersections, even with some white crossings present, is justified.[6–8]

The findings described above can also apply to embossments detected on the back of a page caused by writing on the front and hence the sequence of writing on the front and back of one sheet can be determined. Both sides of the sheet can be examined by ESDA to corroborate the findings. This is of importance if the relative timing of entries in a diary is in question.[9]

The method can also be used to establish that all the writings on one side of a page were not made at the same time if some were shown to have been made before writings on the reverse and others after them.

Sequencing of Office Printing

Although typewritten documents are now rarely produced, they may still be found in cases that involve old documents. The determination of the order of two typewritten entries made with liquid inks from fabric ribbons is, like those with similar inks from pens, unlikely. Again, the coloring material is taken up by the paper and does not rest on the surface. Similarly, typewritings made by these ribbons that cross pen lines provide little or no evidence of their order of stroke.

Determination of stroke sequence when carbon ribbons, which operate by depositing a piece of plastic film in the shape of a letter, are used is more successful. Deposits from carbon ribbons are examined by scanning electron microscopy. If they cross lines made with ballpoint inks, the sequence can be determined by observation of the relative position of each material. Their surface is also affected by pressure from the point of the pen, and evidence of this can be found by careful observation of the enlargements.

Scanning electron microscopy of crossed lines may require the crossing to be removed and placed in a small chamber in the instrument. It is therefore partly a destructive method, and if the document must not be damaged, it cannot be used. Although the piece of paper removed is not destroyed and could be examined later by another expert, the document cannot be restored to its previous condition. More simply, it may be possible to lift carbon ribbon with a scalpel at the point of the intersection and discover whether an ink line is present below it, showing that the ink writing was made first.

Ballpoint ink lines crossing over laser-printed entries remain on top of the fused toner and can be observed most clearly by their specular reflectance under low magnification, but liquid inks from fountain, fiber-tipped, or rollerball pens will soak through the toner and not be visible. The fact that laser-printed documents bear fused toner particles over the whole surface of the paper can be used to sequence typed material and ballpoint inks even if the entries do not cross. Whether the fused particles are over or under the ballpoint ink can be determined microscopically.[10]

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The Functions of Imaging in Document Examination and Other Special Techniques

10

Imaging

There are three main functions of imaging in document examination: to make a permanent record of the document before it is damaged in the course of certain examinations, to detect certain features that are not visible and for which other methods are unavailable or less convenient, and to prepare material from which demonstration charts for use in courts are prepared.

Record Imaging

Although the document examiner will avoid any damage until all other methods have failed to give adequate information, there are tests for inks and other materials that appear on a document as well as for the paper itself that require a small quantity to be removed. Other tests, such as those for fingerprint detection, stain the whole document, and, rarely, may damage the writing. Dry-transfer lettering or newspaper cutouts may become separated from the paper on which they are placed when this is treated for fingerprints.

A properly prepared image of a document can display most of the information visible on the original and can therefore be used as a substitute for it in a court or in preliminary investigation. The preparation of a high-quality image made for a record now usually involves scanning or digital imaging rather than conventional photography. In making an image, the document should be handled as little as possible and excessive contact with any surface should be avoided. Some laboratories requiring a lot of record photography may have a permanent stage that can be easily cleaned with an associated digital camera mounted above it. This is easy to operate and ensures correct focal length and an image of the appropriate size. When occasional imaging is required, a standard photocopier or scanner may be used, but in doing this, care must be taken not to alter the document or the image. Without it, there may be distortion caused by the document not being flat on the platen of the scanner, the image may be angled if the document is not laid square on the platen, and the image may be poor if appropriate settings for the scan have not been used. There is a temptation to use modern scanning techniques that require the document to be rolled through an inline scanner, which allows multiple pages to be processed at one time. This should be avoided as this will alter the document, for instance, by adding roller marks and pick-up marks, and may introduce dirt from the roller. A flat-bed scanner is quite sufficient if cleaned before the introduction of each page.

Color images have considerable advantage in that they show differences in the color of inks, but they have limitations, especially when printed, as the true colors may not be accurately reproduced. Digital images for record purposes, whether produced by scanning or digital photography, are often stored in an uncompressed file format, although the most recent compressed formats do not significantly reduce the quality of the image. However stored, the original file should not be subjected to any subsequent image manipulation, which should always be done on a copy of the file. If stored electronically, the system must be auditable to demonstrate that the image is original.

An image taken as a record, although of good quality, will not always be an adequate substitute for the original document for scientific examination. Without the right settings, it may not be possible to detect evidence of tracing or other impressions, and without adequate magnification, the method of the construction of the handwriting may not be visible. In many cases, particularly with high-resolution images, it is possible to find on an image adequate material on which to base a firm conclusion if the document is no longer available or is not in a suitable condition for direct examination.

Record imaging should be done prior to any subsequent activity such as fingerprints or searching for DNA so that a true record is made. This may require anticontamination precautions to be taken, and a digital photograph, rather than a scan, may be a better way of doing this, as it requires no direct contact with the item.

Recording Invisible Radiations

Imaging is capable not only of reproducing what can be seen but, in certain conditions, also recording what the eye cannot detect. Many conventional digital cameras contain software or lenses to eliminate ultraviolet and infrared imaging, but specialist imaging equipment may be purchased that is sensitive to both ultraviolet and infrared radiation as well as to x-rays, none of which are seen by the eye. Techniques that employ those invisible radiations to differentiate between inks or to reveal erasures or watermarks can therefore use imaging as a primary method of detection and to provide a permanent record of the findings.

The significance of infrared absorption, ultraviolet and infrared luminescence, and x-ray absorption has been dealt with elsewhere. The detection of the latter in document examination is exclusively achieved through some form of imaging.

Luminescence in the visible range of the spectrum excited by ultraviolet radiation can be imaged using a filter, which prevents the exciting radiation from falling on the CCD. Infrared radiation can now be recorded by CCDs, but originally was detectable only by photography. Document examination workstations such as the Foster and Freeman VSC range make these images easily accessible.

The Use of Filters

Apart from the separation of infrared reflection or luminescence from a background of visible light as described previously, filters can be used to increase the contrast between two parts of a document. A filter that allows light of only a certain color to pass will cause writing or marks of that color to disappear. This enables irrelevant background printing or marks to be rendered partly or completely invisible. A partial obliteration of a black ink with a blue ink that cannot be interpreted by other means can be viewed or imaged through a deep blue filter. This has the effect of reducing the intensity of the blue obliteration without affecting the black entry and may provide sufficient contrast to solve the problem. The reverse situation, the identification of an obliteration with black ink, cannot be helped in this way because no colored filter can allow black areas, caused by a total absorption of all wavelengths, to appear lighter. Although it can be done with physical filters on the original document, this can also be done electronically on a digital image of the document by using appropriate software.

The examination of some partial obliterations, even when imaged through filters, will not be aided by attempts to increase contrast in the image of the two inks. However, imaging can assist in these cases. An enlarged physical or digital image of the obliteration can be made, and those parts that are clearly from the obliterating ink can be visually removed by covering them, leaving only those traces that appear to be from the obliterated entry. By repeating this with a number of different techniques, various parts of the original entry can be revealed; by overlaying these, the image of the obliterated entry can be built up. The interpretation of these is much less difficult when they stand apart from the obliteration. Often, this is easier to do on the physical image, but with appropriate software, this can be done electronically on the image file. In this case, it is important that the operator clearly understands what the software is doing to avoid the creation of artifacts that could be mistaken as evidence.

In some cases, where the overwriting ink cannot be rendered invisible by filters, but where that which is required to be identified can be, an ingenious method can be employed. A negative image is made of the document, using a filter that makes the required entries invisible, and a second image of the same area is made under conditions that make the contrast of these entries with their background as high as possible. A positive transparency is made of the second image, and it and the first negative image are placed together so that their images are exactly superimposed. The negative image will tend to cancel out the positive overwriting and the background and leave the image of the required entry unaffected. Some adjustment of the intensity of the images is necessary to achieve the right balance, and a combined image can be produced. Again, this can be achieved electronically with the appropriate software. In certain cases, the technique can be very effective.

Imaging for Demonstration Charts

While courts increasingly have access to good imaging and information technology (IT) systems, when producing images for demonstration purposes, it is still best to make a physical document that can be exhibited, duplicated, and given to a jury. If the courts then wish to display this electronically, then they may do so, but having a physical image fixes the image and provides a permanent record for the court once the live expert testimony is over. The chart should be kept as simple as possible and not include images that are not easily understood, such as spectra. The idea is to demonstrate the findings, not to justify them. If produced well in advance of a court and served on the defense, it may prevent the need for a court appearance at all.

Much of what is needed to prepare charts for the demonstration of the conclusions of a document examiner in court has already been covered. The most common need is for images of writing to be made to demonstrate the similarities and differences apparent between the known and questioned writings. In such cases, the writing rather than the whole document can be imaged to provide maximum resolution when the final chart is printed.

In contrast to record imaging, where every detail of the document should be reproduced, it is sometimes an advantage to remove from the picture those extraneous features that have no bearing on what is to be demonstrated. The colored security background on checks, or the marks made by a bank cashier across the signature, are often of a different color from that of the questioned writing and can therefore be removed from the image using appropriate imaging software.

It is not necessary to print each example of writing with the same magnification. In some cases, large writing has to be compared with small, and it is clearly advantageous for the images of both to be approximately similar in size when their detail is being demonstrated. Size is not an important factor in many comparisons, and because the documents themselves or copies of them will clearly show that there is a dimensional difference, any confusion should be minimal. The more important similarities or differences in detail are more clearly appreciated if both known and questioned writings are shown similar in size.

Differences in inks, restored obliterations, erasures detected by infrared radiation, or luminescence excited by ultraviolet are usually clearly visible on a monitor screen and, in many cases, on any subsequent printout. In such cases, the printout is suitable in itself as a method of demonstrating the findings. If the result is not clear on a printout, then it may be possible to illustrate it by having the image displayed on an available monitor screen. Where images are used to demonstrate findings, it is helpful to those to whom the findings are to be demonstrated if normal-light images are also included. This enables a "before and after" comparison to be made.

Imaging of indented impressions is often useful to show guide lines from which a signature has been traced or to demonstrate the impressions themselves if electrostatic methods are not available or do not work for the particular case. Illumination of the document from a source nearly parallel and close to the paper casts shadows in the impressions and makes them visible in an image. However, to achieve satisfactory results, considerable care is needed. Again, a normal-light image contrasting with that taken in oblique lighting will be of assistance.

Examination of Photographs as Questioned Documents

Traditional film photographs, as opposed to digital images, are themselves, on occasion, questioned documents. It may be necessary to identify the camera in which the negative was made. The masking frame in the camera may have irregular edges, caused by damage or dirt, that leave their images on the film exposed in the camera. Because the irregularities are normally sufficiently random to allow for no practical chance of coincidental match, the evidence linking a negative, and perhaps prints made from it, to the camera can be extremely strong.

Photographs can be faked by the addition of parts of other pictures and rephotographing. Edges of cutout parts of another print may be detected, and inconsistencies in shadows or focus may provide clear proof that the photograph is a composite. Examinations of this type require expertise in both the theory of photography and its practice and are not normally regarded as within the province of the document examiner.

With digital images, the point at which examination of them becomes the role of an imaging specialist as opposed to a document examiner is unclear. Most document examiners would treat images of documents, and manipulations of them, as within their area of expertise. However, where the digital image is essentially a photograph, a document examiner who was not also an imaging specialist would be best to regard it as outside his or her specialty.

Live Viewing Techniques

Infrared and ultraviolet radiations are invisible because they are outside the range of wavelengths the eye can detect. Some detectors, such as CCDs, can be very sensitive in the infrared region. The Video Spectral Comparator produced by Foster and Freeman Ltd. (Evesham, Worcestershire, UK), has been designed especially for document examination and contains in one unit all the techniques required to detect and record differences in inks on documents.

The latest version, the VSC8000, incorporates a range of light sources and filters connected through a computer to a high-resolution color monitor and enables a wide range of examinations to be carried out, some automatically (Figure 10.1).

The VSC provides a convenient package for many lighting examinations, but many of the techniques described can be carried out in a well-equipped lighting and photographic studio or using dedicated equipment. A light source of value in document examination is the Polilight produced by Rofin (Australia) Pty. Ltd. (Dingley, Victoria, Australia). This uses a tunable interference filtering system and an intense light source to produce illumination of continuously variable narrow ranges of wavelengths. It will detect differences in luminescence of inks that are dependent on variations

Figure 10.1 The video spectral comparator (VSC 8000) made by Foster and Freeman Ltd. (Evesham, Worcestershire, UK). This instrument enables examination of documents in infrared and ultraviolet luminescent and absorption conditions to be carried out. A document placed inside the cabinet is viewed on the monitor screen. A wide variety of lighting conditions are available for the observation of the document as well as image processing facilities.

Figure 10.2 The Foram 3 made by Foster and Freeman Ltd. (Evesham, Worcestershire, UK). This instrument enables the capture of Raman spectra, a form of vibrational spectroscopy that can assist in distinguishing between different inks.

of the wavelength of the exciting light. The resultant luminescence can be detected by suitably sensitive digital cameras or by using the Poliview made by the same manufacturer.

An apparatus specially designed to apply Raman spectroscopy to forensic document examination is the Foram 3 Raman spectrometer, manufactured by Foster and Freeman (Evesham, Worcestershire, UK), which extends the range of techniques for the nondestructive comparison of inks (Figure 10.2).

Processing

When a digital image is produced, it consists of many points called “pixels” (picture elements). Software adjustments can alter these pixels so that the overall picture is changed; such changes can be exploited to enhance various features of the image. Software is now readily available that will allow a wide range of manipulations to be carried out on a digital image.

The processing of the picture may involve basic operations such as edge enhancement and increase in contrast, or more complex tasks. Whatever changes are being made to a digital image, it is important that the original image be kept and only copy files are manipulated. Image manipulation should be kept to the minimum required to resolve any issues; it is very important that such manipulation does not result in the creation of artifacts that might be mistaken as evidential features.

High-resolution images on a monitor can be viewed in various ways, such as side by side or superimposed, to allow two documents, or the same document under different illumination conditions, to be compared. The facilities to carry out this sort of work are incorporated into such equipment as the VSC8000.

Optical Microscopes

Magnification is an important feature of document examination. Enlargement can be produced using imaging techniques, and high-resolution imaging can now be almost as good as seeing the original document. However, the optical microscope is the most frequently used tool of the examiner. There are many arrangements of lenses and lighting systems that are described as microscopes, but the stereo-zoom microscope, which gives a magnification of around 10–50× with a relatively wide focal range, is the most suitable for document examination. The zoom feature, if properly set up, will allow the document examiner to go from 10 to 50 times magnification without needing to adjust the focus. Lighting can be provided from any direction, but for most examinations, illumination from above is most convenient. Most commercially available stereo microscopes provide a range of magnifications using either a series of different lenses on a turret or a zoom lens, which gives a continuously variable range.

The mounting of the microscope head is important. For the examination of documents, the most suitable way is on a long arm, rather than on a compact stand. The arm allows the document to be positioned on the bench and provides adequate room for a large document and for its easy movement. It also gives the operator freedom to vary the direction of the light falling on the field under examination.

Smaller magnifiers can be obtained that do not have the power, flexibility, or ease of operation of the stereo microscope but are more portable. Magnifying glasses and handheld instruments with a built-in light source that can give magnifications of up to about 10× may be satisfactory for the examination of handwriting because they enable the method of construction of certain letters to be determined when this is not possible by direct vision. Other hand lenses or magnifying glasses providing enlargement of 2 or 3× are usually of value to examiners of middle age whose visual accommodation has declined and who find close observation difficult. They enable little extra to be seen by those capable of examining a document from a distance of a few inches, but assist those who are unable to do so. Similar instruments, such as large lenses with a surrounding light source, fulfill the same function.

Comparison Microscopes

Comparison microscopes have a system of optics that display images from two objects through one lens so that they can be observed together. In some instruments, the observed field is divided into two at a vertical line, each object occupying one side. Close comparison is therefore possible, but no provision is made for superimposition of two areas. The method is more suitable for the examination of fibers or bullets, where a continuous similarity or difference along the length of an object can be observed. If the dividing line can be moved, some comparison of area is possible, but generally, this method is less satisfactory in document examination than full-field comparison methods, those where the images of two documents can be superposed. With digital imaging, it is possible to show both documents together superimposed and apparently occupying exactly the same area, but in these circumstances, it is not always possible to be sure on which document a particular feature occurs. This can be overcome by the provision of an oscillation facility, so that first one and then the other document is observed in the same position. The rate of "strobing" can be varied so that any difference between the two images is shown either by the flicking off and on of a feature present on only one document or an apparent movement of a feature that varies in position between the two documents. Either or both documents can also be illuminated with different colors or viewed under special lighting so that contrasts can be observed. Methods that superpose electronic images of documents are now available so images of the same document under different lighting conditions can now also be compared. These software packages are included in devices like the Docucenter NIRVIS, made by Projectina, and the VSC8000, produced by Foster & Freeman, but many software imaging programs will allow this sort of image manipulation.

Scanning Electron Microscopy

The final limit to greater magnification with the optical microscope is determined by the wavelength of light. This is known as the resolution of the microscope, that is, the ability of the system to distinguish between two adjacent points. Higher resolution and therefore higher useful magnification can be achieved by "illuminating" the sample with electrons, which have very short wavelengths. However, just as information can be obtained from the chemical as well as the physical interactions of infrared, visible, and ultraviolet radiation with the sample, so the use of electrons provides more than a high-resolution image.

The scanning electron microscope is an instrument for observing the various phenomena that occur when a finely focused beam of electrons is scanned in a line and frame raster across the surface of a sample. The most important of these are secondary electrons, backscattered electrons, and x-rays.

Secondary electrons are emitted by the sample itself; they are collected and processed to form a topographic image, which is displayed on a video monitor. Magnifications of 100,000× or more can be obtained, although the upper limit of useful magnification is usually determined by the nature of the sample rather than by the wavelength of the electrons in the primary beam. The image has great depth of field, typically 300–400× that of an optical microscope, and it is this property, rather than high magnification, that is more important for the examination of documents. In fact, the instrument is often used for such problems as determining sequence of writing and identifying dry-transfer lettering and photocopied materials at magnifications well within the range of the optical microscope because of the greater depth of field that can be obtained.

Backscattered electrons are electrons from the primary beam that have been reflected from the surface of the sample. The proportion of incident electrons reflected is related to atomic number; elements such as chromium, iron, and lead produce more backscattered electrons than carbon because they have higher atomic numbers. This property is useful for distinguishing between inks of the same color but with different chemical compositions and for imaging what is beneath an alteration that is opaque to infrared.

Finally, the elemental composition of the sample can be determined by collecting x-rays emitted as a result of the electron bombardment and measuring their energies. All elements from sodium upward in the periodic table can be detected. The analysis is displayed either as an x-ray spectrum or as an image showing the distribution of a particular element across the surface of the sample. Printing and security inks and the various mineral components of paper can be analyzed, although little or no useful information is obtained from many ballpoint and water-based inks because they contain chemical elements that cannot be detected by x-ray spectrometry.

For the best results, the area of interest on a document is coated with a thin layer of carbon or gold by vacuum evaporation to render the surface electrically conductive, although this can be dispensed with in certain cases by carefully masking with metal foil those parts that are not to be examined. Items as large as a sheet of newsprint can be examined without sampling provided that they can be folded and are able to withstand the high vacuum of the sample chamber. If sampling of a document cannot be avoided, damage may be minimized by punching out small discs with a modified hypodermic needle. The resulting holes are often visible only when the paper is held up to the light.

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Document Examination in Court 11

Introduction

The conclusion that a forensic scientist expresses in his or her report will be directed to his or her client. It may be favorable to the client's interests or it may not; it may be too inconclusive to be of any use either way. In many cases, the final outcome is a hearing in a court of law. Often, this is avoided by a settlement beforehand, a plea of guilty, or a decision not to prosecute in a criminal enquiry, but many reports and statements of a document examiner are liable to be the basis of an eventual testimony from the witness box.

There are different proceedings in the two branches of courts, civil and criminal. In each, however, it is necessary to present to the judge or jury the conclusions, their strengths and weaknesses, and the reasons for them. Usually, evidence that is not disputed can be read without the attendance of the expert. This means that the original report or statement must be sufficiently clear and unambiguous to be properly understood. Nevertheless, if the examiner is present in person to explain the findings and to interpret points that may be of particular interest to one or both parties, there may be a considerable advantage to the judge or jury.

The Conduct of the Witness

The technique of giving evidence is of considerable importance in the work of document examiners. Without the ability to convince the court of their conclusions, all the work they have done previously will be wasted. A correct conclusion reached perfectly may be lost in the confusion of a situation in which the examiner is not able to present the findings adequately. In contrast, a properly prepared performance, clearly presented and, if required, well illustrated, will convince the court of the validity of the conclusion. The aim should be not to proclaim the opinion as undeniable, giving no grounds for it other than the status of its originator. Rather, the witness should argue the reasons in a logical, precise, and convincing manner so that the judge and jury will be persuaded by the evidence and appreciate for themselves that the conclusion is justified.

Dress

The bearing of witnesses is of importance. The judge or jury will be impressed by what they say, depending on its clarity and logic, but other factors such as appearance and dress may not be ignored. A survey in the United States showed that most people expected the expert witness to be smartly and soberly dressed. Although there is now less formality in dress and more attention is likely to be paid to what is said than to the more superficial personal appearance, a lack of courtesy may be inferred from unsuitable attire.

Manner of Giving Evidence

The evidence is essentially for the judge and jury, not for the counsel calling it, so the questions are best answered not to counsel, but to the jury or judge. As the latter will be making detailed notes of much of what is being said, glances in his or her direction will indicate the speed at which the evidence should be given. The jury will more appreciate the expert if the expert directs evidence to them, and, by observing the jury's reception of their words, witnesses will notice whether they are making themselves clear.

Technical Evidence

Evidence on technical subjects needs to be appreciated by the jury. They will have previously heard evidence of fact from lay witnesses, which is for the most part within their experience, but expert evidence differs in that the subject is not familiar. The witness must therefore make allowances for this and use plain language. Those areas where technical terms must be used present a particular difficulty. Care needs to be taken to avoid expressions that are so familiar to the specialist that he or she forgets that these terms will not be comprehended by others. The best policy is to explain the technical features of the evidence in language simple enough for the nonspecialist to understand, but at the same time avoid oversimplification if this will diminish the truth. Generally, when a term is first used, it should be described briefly, after which it may be used without further explanation, or perhaps with brief reminders. More complicated methods, such as infrared absorption or scanning electron microscopy in its analytical mode, are difficult to explain to a jury. This is, however, rarely necessary, because conclusions based on such techniques are infrequently challenged. In contrast, handwriting comparisons and their conclusions are more easily understood and are more frequently disputed; these and other examinations are discussed in more detail later.

If the evidence is not fully understood and appreciated by the judge or jury at an early stage, the cross-examination will be able to increase any unwarranted doubts that may already be there. In an adversarial situation, it is not for the opposing counsel to clarify what their opponent has left uncertain unless it is to their advantage. In this situation, even the most experienced and able witness may not be able to convince their listeners of the validity of their evidence.

The Role of Counsel

To present the evidence to its best advantage in the adversarial context of the courts, the expert requires the cooperation of the counsel introducing the evidence. It is their job to maximize its effect for their own case, but if they know that it is already accepted by the other side, they may simply ask what the conclusions are and leave it at that. Unfortunately, this practice may extend to those cases where there is a contest and the evidence-in-chief, the first testimony of the witness, is not adequately presented. The attitude that it is up to the expert merely to express the findings, and if the opposition wishes to challenge the expert, they may, is not the ideal way of presenting technical evidence, especially evidence on handwriting.

Conferences

For counsel introducing the testimony to do so in the most effective way, a conference with the expert is often helpful. There are many reasons for this. First, counsel can make it clear in a complicated case what parts of the evidence they will be referring to and in what order they will introduce them. Second, experts can make clear the reasons for their conclusions and the strengths and weaknesses. They can indicate what they might reply to certain questions if they occur in cross-examination; it is advantageous if their later answers do not surprise the counsel calling them. A general discussion, both of the principles involved in the particular examination and its specific significant details, should ensure that all parties are on the same wavelength. Normally, even in criminal trials, expert witnesses are able to be present in court to listen to any evidence that bears on their own and to the evidence of opposing experts. Whether and when the expert is to attend is one point that can usefully be cleared up in conference.

Cross-Examination

The purpose of cross-examination will vary from case to case. In some, the whole of the evidence of the document examiner is contrary to the interests of the opposite side, and in others, only part of the evidence is in dispute. In other cases, the only point to be clarified is one that may have been of marginal interest to the expert at the time of the examination. It is sometimes of value to the cross-examiner to emphasize a point already made in evidence-in-chief to make sure that it is appreciated by the judge or jury. Occasionally, further examinations on the same or different documents are required, and these are requested in cross-examination.

The difference most noticeable to the witness is that the questions put in cross-examination are usually not as predictable as those in evidence-in-chief. While the latter will follow a statement or report prepared by the expert, perhaps in a way agreed upon in a conference, those put by the opposing counsel will not be entirely anticipated. Although the purpose may be merely to clarify some points or to emphasize an uncertainty already expressed, it may also be to discredit the witness or, at least, the conclusions.

In a debate or agreement in a meeting or in a social exchange, a view may be expressed that is hotly contested. In the courtroom, however, the expert witness is in a public place, perhaps with the glare of media coverage. What the witness says will be noted by more than a handful of people, perhaps reported at length. In these circumstances, the witness is placed in a far more vulnerable position than another scientist presenting a paper at a meeting or symposium, and any mistake will be of greater significance to his or her reputation. Such a mistake may be over a small detail rather than an important conclusion, but in the adversarial system, it may be magnified out of all proportion by the cross-examining counsel.

It is therefore of vital importance that experts in the witness box be fully aware of all the aspects of their evidence and its background. Apart from answering questions truthfully and accurately, they may need to foresee what the next question will be. Too much conceded in one reply may lead to a further answer that reduces the strength of the evidence to a degree that does not represent the proper conclusion. It is not the sole object of counsel cross-examining to elicit the truth, but to reduce the evidence to a position most favorable to their client's case. The witness, however, must keep to the truth, conceding a point if that gives greater accuracy than an earlier answer, but not bending to pressure if it does not.

In normal argument or debate outside of a court of law, the bearing of the opponents will be of less importance than the points they make. In the witness box, however, the expert will be to a large extent judged by his or her demeanor. This is tested by the pressure of cross-examination. Experts' attitude must be dignified, courteous, and polite, and they must be fair but firm in their answers. Little is gained by trying to score points off their opponent, even if the temptation to do so is sometimes very great. In the long run, a far better impression is given by a patient but authoritative dignity than by an argumentative display.

There are, however, occasions when firmness is necessary. A tactic employed by some counsel is to interrupt an answer if it appears to be going the wrong way. If this is not stopped by the judge, witnesses should make it clear that they will not be deflected from finishing their reply. A lack of respect or courteousness on the part of counsel is best treated with disdain, but there are times when it is better to make it clear that it is not appropriate. The most crucial point for witnesses to remember is that in such situations a loss of temper is very damaging to their bearing.

In most cases, however, the cross-examination of an expert witness is carried out along far more civilized lines, and the evidence is tested by logical questioning about the methods employed in the examination and about the validity of the conclusions reached. From the point of view of the cross-examiner, there is a need to reduce the evidential value of the testimony to a point where the judge or jury will regard it as unsound, unreliable, or even mistaken. If the conclusion is soundly based, the cross-examination is likely to fail, but if it arises from inaccurate observation or reasoning, effective questioning will expose this.

From the point of view of the expert witness, cross-examination can be testing or merely time wasting. If the observations and conclusions are correct, the questions will cover ground already considered. A properly based conclusion will have already taken into account all the points that may have indicated an opposite result or an expression of uncertainty. Clearly, if there are reasons for reconsideration, they must be accepted; pride or stubbornness cannot be allowed to take precedence over an admission of an error.

The task of the cross-examining counsel is not easy; as a layperson, they need to understand the methods of working of the expert, the techniques, the findings, and the deductions. Counsel may be assisted by an expert of their own who may or may not agree with the findings of the witness. Little is gained by a personal attack, which rarely impresses, or even by an appearance of incomprehension, which may not be shared by the listeners. A better and more effective attack is by careful consideration of the qualifications of the expert and the observations and deliberations that led to the conclusions. An erroneous opinion will be difficult to maintain if the questions are properly directed to these issues, but can be left unscathed if the only challenge is one based on the integrity of the witness.

Further Examinations

Giving expert evidence on document examination is not always a straightforward procedure; although the basic pattern of testimony is the normal practice, complications sometimes occur. One of these is that other documents, not previously seen by the examiner, are presented for comment. This practice should be resisted because it is not possible to form a properly considered conclusion in such a short time without adequate resources. Although it is possible to use a small magnifier in the witness box, there may be a need for higher enlargement; sometimes the use of infrared radiation or similar, more elaborate techniques, may be required. It is, however, not so much the lack of equipment that is likely to be a problem, but that the time and conditions required for proper consideration of the observations are not available. It is not unreasonable for the witness to make observations about the document he or she is examining in these circumstances, but it is unwise to make any deduction from these observations unless it is very cautiously expressed or it is very obvious. A desire to assist the court may be commendable, but the chance that it may be misled by a hastily arrived-at opinion has to be considered. It also must be appreciated that the request for a conclusion may not be a need for information but a trap. The right answer may already be known, and if the wrong deduction is made, the rest of the evidence will be discredited. The fact that this had been properly arrived at in contrast to the instant opinion on the new material may well be lost. Equally, it may later be suggested that a refusal to state something that is obvious indicates an unwillingness to assist the court with unbiased evidence.

In most cases, it is better to offer to take the new document away and return later with a fully considered answer. It may be possible to do this after a short time by examination of the items in the court precincts, or it may be necessary for a proper examination to be made in laboratory conditions. Either way is preferable to expressing a conclusion from a witness box examination, and a request for such conclusion should normally be refused.

Opposing Experts

The theory that it is always possible to find another expert who will say the opposite of the first does not apply to document examination. Although there are many examinations carried out by both sides in legal disputes both in the criminal and civil fields, the appearance of two experts giving different conclusions is relatively rare. It is, however, a situation that does occur on occasion, essentially for one of two reasons: it is either a genuine disagreement by two competent and honest examiners or it is due to a lack of ability or integrity of one or both of them.

The first circumstance is unusual, especially in those cases when there is a radical disagreement. More often, a difference in the strength of a conclusion is encountered; one expert may consider the evidence stronger than does the other. In such cases, both the examination-in-chief and the cross-examination should clarify what each person is saying, because the difference may be no more than the way in which the conclusions are expressed. The problem of making technical evidence clear is not always solved in a statement or affidavit and can continue into evidence, but the appropriate questions may clarify the position and testimony show that the conclusions of the two experts are not so far apart. Another reason for disparity in conclusions in handwriting comparisons may be that the known writings are different, and each examiner has worked from a different basis.

In the United Kingdom, courts may order opposing experts to meet and produce a joint report detailing those areas on which they agree and those on which they do not. The actual court hearing can concentrate on dealing with the areas of disagreement. Where there is disagreement, both points of view will be put before the court, which must then decide between the two, taking other evidence into consideration, and reach a verdict by whichever standard of proof applies.

Incompetent Examiners

The second occurrence, that of an incompetent practitioner, is a different matter. The methods used to examine handwriting and to draw conclusions from the examination are not impossible for the layperson to understand. The logic of the approach and the accuracy of the observations can be tested by cross-examination, and this should show up incompetence. This is not always achieved because the counsel cross-examining may not be sufficiently aware of the proper methods and finds themselves baffled by the apparent credibility of a complicated explanation of erroneous findings. Even if the credibility appears to be lacking, they may discover that it is difficult to break down the certainty of the conclusion and the confidence with which it is given.

The assistance of the expert whom they will later call or who has previously been called will be of value, but this is not always possible. If notice has been given, its detail may not be as full as that given from the witness box, so decisions on the line of cross-examination and on the individual questions must be made quickly. The best question, like the most appropriate answer, may not be formulated until it is too late. It is the experience of many involved in litigation, both as counsel and expert witness, that the best questions or answers are thought of on the way home from court.

It is necessary, therefore, in countering erroneous conclusions for the cross-examiner to be aware of the correct approach to the subject and the details of the particular case. A conference before the opposing expert gives evidence is advisable so that counsel is aware of these details. In addition, the presence of their expert behind them is advantageous. Although the communication between the two is not easy, with counsel on their feet and the seated expert whispering advice or passing hurriedly written notes, points that may be profitably put to the witness can be communicated to the cross-examiner. Most judges are willing to give time for a short consultation in court between counsel and their expert while the witness awaiting cross-examination is still in the box.

Presentation of Handwriting Evidence

When giving evidence on handwriting, it is best that the expert describe the findings and the reasons for them at some length, so that the judge and jury will see for themselves why the conclusions have been reached. From this position, the cross-examination will not be as effective in reducing the impact of the testimony.

The desired results can be achieved either directly from a consideration of the writings in question or, preferably, by a short outline of the principles of the method employed followed by a demonstration of the application of those principles to the handwritings before the court. The general principles can be described verbally with appropriate clarifying questions from counsel if it appears to them that the principles are not fully understood, but the details of letter construction and proportions are best shown by enlarged images specially arranged to show the features of interest.

Demonstration Charts

The usual method in the United Kingdom of preparing such images for court is to prepare charts showing the known and questioned writings in juxtaposition so that the comparison between them can best be demonstrated. Alternative methods such as images displayed on monitor screens may also be used.

To prepare a chart, enlarged images of the documents, both the known and questioned writings, are made. If the writing is large, little enlargement will be needed, and in some cases, a reduction in size is appropriate. When the writing is particularly small, a greater increase in size is required. The object of the choice of dimensions is to produce an illustration of that detail in the handwriting that is of importance in the examination; provided that this can be comfortably seen, the actual degree of enlargement is not important.

Interfering colored backgrounds that have no relation to the writing can be "removed" from the image either by the use of filters when the image is recorded or by subsequent software manipulation of the image. This may be difficult if the unwanted material is close in color to the writing in question, but can be very successful if it is not. Other features such as dotted lines or writings on forms may be better left in to show how they relate to the writing.

Suitable images having been obtained, the chart can easily be prepared by electronically copying and pasting the images or parts of them into a new document and then printing out the resulting file. A high-resolution printer should be used for this, but most current laser printers can produce output of an appropriate quality. The chart may be based on whole documents or individual words if the writings are similarly worded, or the individual characters can be displayed separately. Most often, individual words from the known and questioned writings are positioned in separate but adjacent areas. The same word occurring in each, or words containing the same letters, are placed opposite each other, sufficiently close for a comparison to be made.

The choice of what to put on a chart is important. If it is possible to show all the writing, this should be done, but in many cases this is impracticable. What is needed is sufficient writing to demonstrate how each letter is made and how it compares with the known material. It may be best to use all the writings of one or two documents to represent the whole of those that have been compared, rather than to select small amounts from each. The writings chosen should be representative of the whole; those that favor the conclusion should not be picked out to the exclusion of those that do not. Similar considerations apply when it is required to show the differences and other reasons a conclusion that signatures and other writings are simulations has been reached.

For courts in the United Kingdom, the chart is copied so that everyone in court who needs to can study it. A projected image on a large screen can be used in those countries where the topography of the court and its practices allow it. Where this is not possible, sufficient copies of the chart should be printed out for the judge, counsel, defendant, and jury; fewer are required in a civil court. The jury is usually provided with one copy for each two jurors. They are then able to assist each other in identifying what is being referred to by the witness or counsel.

When the charts are used, the witness should make clear, and should therefore be asked to point out, where each example appears on the document in question. He or she can then be asked to deal with as many letters or other features of the writing as is necessary to demonstrate the findings to the court, referring to the chart to point them out. Differences as well as similarities should be noted; it is best not to allow these to be first mentioned in cross-examination.

The giving of expert evidence, like other evidence, is by question and answer, and although the expert will be allowed to expand for longer periods than would a witness of fact, there is clearly a need for counsel to ask the right questions. In some ways, the testimony can resemble a lecture, but, properly handled with the right questions, can be more effective. What may be unintelligible to the listeners of a lecture can be clarified by an interruption by counsel when they realize that a point is not fully understood.

It is best for the witness to avoid jargon except where it is necessary, and then the term used should be explained. Some people believe that the knowledge and use of specialist terms give an air of authority to the speaker, but the aim of the handwriting expert in court should be to enable the judge or jury to appreciate the reasons for the conclusions, and not to blind them with terms that they do not understand. Sensible laypeople will not be fooled into believing a witness who confuses rather than clarifies.

The writing should therefore be referred to in plain and simple terms, and the court should be led through what detail is needed. How much is required is best left to the judgment of counsel. An enthusiastic expert left to his or her own devices may go on far too long, but when counsel is satisfied that enough has been said to convince the court, they can bring that part of the evidence to a conclusion. It is sometimes a good idea to allow the listeners to find a few more similarities on their own without being shown.

When the details shown on the chart have been demonstrated, it is useful to reiterate the principles of handwriting comparisons and repeat the conclusions reached.

Evidence Other Than Handwriting

Presentation of the results of those areas of document examination that do not concern handwriting requires other considerations. While, despite its complexity, handwriting examination can be understood by the layperson, techniques such as infrared luminescence, scanning electron microscopy, or electrostatic detection are outside the experience of most people. Some attempt must therefore be made to indicate to the court all the reasons for the conclusions arrived at using these techniques, especially if the evidence is disputed. In using illustrations in court, the document examiner must bear in mind that it is exactly that: an illustration. The chart must therefore not attempt to turn the jury into experts, must not try to baffle the court with science, and must be a standalone document so that, once the expert has vacated the witness box, the chart is still understood. Consequently, many examinations are not suitable for presentation on a chart, although there are some types of document examination that are visual in nature and therefore can make effective charts.

Special Photography

Charred documents can be imaged in the most suitable conditions to enable a court to read what was written or printed on them before they were burned. Other forms of damage may make a document difficult to read, but an image can provide a record for the benefit of the court.

Images made of a small part of a document greatly enlarged are of particular value to show certain features otherwise indiscernible by a court. Examples of these are the demonstration of guide lines in traced simulations and the illustration of how an underlying figure has been overwritten to alter it.

At greater magnification, images taken from the scanning electron microscope can be produced in court. These, however, present problems to the layperson in that what they show is not within his or her experience. While an enlarged signature can be recognized as such, the magnification of the scanning electron microscope produces a micrograph of, for example, a printed line crossing ballpoint ink that is unrecognizable. Careful explanation of the picture is therefore needed if it is necessary to use such evidence.

Differences in Inks

Whereas the evidential value of the similarity between handwritings may be of great significance, it is sometimes the difference between two inks that is of foremost importance. Those methods that use infrared reflection, luminescence, or similar techniques lend themselves readily to illustration.

An image produced under those conditions that shows that two inks are different or that an obliterated entry can be read provides incontrovertible evidence in itself. Put side by side with an image of the same area taken in normal light, the contrast is there for anyone to see, whether layperson or document examiner. A fluorescing zero following two nonfluorescing digits may appear white, contrasting with the black of the figures before it, clearly demonstrating that two inks have been used.

The fact that the image shows an obvious difference may make the technical explanation of why such effects occur unnecessary. It is usually sufficient to point out that different inks can react differently in special conditions, and the court will require no more. However, it may be necessary to explain why there are such differences, and it is then up to the expert to put the reason into understandable terms. Any attempt to sound convincing by the use of as many technical terms as possible should be avoided, but oversimplification to the point of inaccuracy is also undesirable. It must be borne in mind that what appears to be a difference between two inks when they are imaged in conditions showing the excitation of infrared luminescence may not be so, but merely a difference caused by the background paper. Such images can therefore be misleading, but it is extremely unlikely that a competent document examiner would not have already excluded this possibility before the picture was produced.

Indented Impressions

When evidence is given about impressions, the court must first be made aware of what they are and how they came to be there. Although it may seem obvious to those accustomed to their detection, it may not be clear to those who have never really thought about their existence. If no explanation is given, one or more jurors could be unaware of what was being discussed.

Oblique lighting images, showing the impressions that are readable under those conditions, will be helpful to the court, but it must be made clear in many cases that other impressions not visible in the images are also present. Similarly, any confusion about what may appear to be raised characters, the effects of optical illusion, must be cleared up. In those cases where the impressions that can be imaged do not include all that have been found, a second image can be made on which all the discovered impressions can be colored in. This gives an indication of the position where those not clear on the first image have been found.

The transparencies produced by the electrostatic detection apparatus can be imaged so that adequate copies are available for inspection by the court. Their origin can be described and the original transparency produced as an exhibit if required. The results obtained from this method are often in themselves sufficiently clear to be read by the nonspecialist.

Mechanical Fits

Where an exact or close fit occurs between two documents, and the word "document" can have a broad meaning in this context, such evidence can sometimes be demonstrated to the court using the actual exhibits. In most cases, however, a more satisfactory illustration of the conclusion can be made by the use of imaging.

Such fits occur in handwriting where tracing has been made from another piece of writing, in the establishment of the source of indented impressions, and in the fit between two torn pieces of paper, as well as in many other areas.

In these cases, images of both documents or their relevant parts can be placed side by side so that the close similarity can be seen. Alternatively, a transparency of one can be made together with a normal print of the other, and they can be hinged together with a staple so that the appropriate parts fit each other. The transparency can then be raised to reveal each document and lowered so that the fit is clearly apparent. Transparencies can be produced cheaply by using photocopiers or laser printers, and they may be perfectly satisfactory for the purpose of demonstrating the fit between two documents.

Not every technique in document examination can be demonstrated to a court. In some, a description may be needed, but in others, it may be impossible for the layperson to appreciate how the test was applied. In some demonstrations, more harm can be done to the clarity of the conclusion if a picture is presented without any guidance from the expert. What may be evident to the examiner and to any other expert in the field may be completely lost on the jury. It is important for the jury not to feel that they have to be experts themselves; no illustration or chart should be shown to the court without the presence of the expert who produced it.

Further Reading

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