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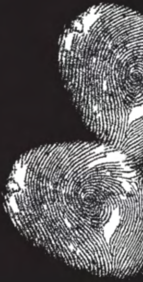
Crime Scene to Court

The Essentials of Forensic Science

Second Edition



Edited by **P. C. White**

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advancing the chemical sciences

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Preface

When the group of forensic scientists had their first meeting with the Royal Society of Chemistry to discuss the proposal for a new forensic science textbook, one of the main points of discussion and concern was whether it would attract a significant market. The decision in the end was to continue and provide a book primarily for supporting the teaching of forensic science degree courses in the UK.

At the time of the first meeting and even when the first edition of *Crime Scene to Court* was published in 1998, there was only a handful of universities offering forensic science courses. However, dramatic changes in universities have since lead to the introduction of many forensic science courses and this book has become one of the recommended textbooks for many of the courses. Hence, when the book was published it could not have been more timely and subsequently has exceeded all our market expectations.

It has also been extremely pleasing to note that the book, as originally intended, has appealed to a much wider readership. *Crime Scene to Court* has been used and referred to by the courts, forensic scientists, police and scene of crime officers and read by lay people who just have a fascination for the subject. Interestingly, although originally intended for the UK the book now sits on many bookshelves throughout the world. This can possibly be attributed to the fact that all the authors are recognised experts in their discipline within the UK forensic science profession, which has an international reputation.

As with any scientific subject technology moves on and hence there was always going to be the inevitable question of a revised edition. Since its publication some forensic practices, both scientific and professional, have changed and when approached all the authors agreed the need for a second edition. Furthermore, the authors were also prepared to give up their valuable time to revise their own chapters, for which I am indebted.

Readers can now benefit from these revisions which provide details of current crime scene and laboratory scientific practices but again the original philosophy of producing a relatively non-technical textbook has been adhered to. As indicated earlier there have also been changes in professional requirements. Maintaining a respected and professional forensic science service is crucial and accreditation of laboratories and individuals, forensic science teaching and quality assurance are all issues which have received considerable attention during the past few years. I am delighted that Brian Caddy, with his extensive professional knowledge and involvement in many of these matters agreed to revise and contribute to Chapter 1 to help address these issues.

This second edition also gave the opportunity to consider if any other forensic disciplines should be included. Computer based crimes in civil and criminal cases have risen dramatically within the past decade and special units have been set up to examine such crimes. Hence a new chapter covering this topic has been introduced. Jonathan Henry provides the reader with the benefit of his considerable experience by introducing how different computer based media store information which, when skillfully restored, can provide evidence for courts.

The other new chapter considered very worthy of inclusion covers the subject of Blood Pattern Analysis. Adrian Emes and Christopher Price, both involved as trainers for the Forensic Science Service in this discipline, explain how information regarding location, sequence of events, disturbance of a scene and even which samples should be considered for DNA analysis can all be gleaned from the careful examination of a blood pattern found at a scene or on an item.

As editor I am grateful for these contributions from the new authors and would like to express my thanks to all authors for their support, valuable time and for providing readers with the benefits of their expertise and experiences. I would also like to record my thanks to the Royal Society of Chemistry for its support and Lorraine Stewart for assistance with the typing.

Peter White

Contents

Abbreviations

AA	Atomic absorption spectroscopy
ABO	ABO blood groups
ABPI	Association of the British Pharmaceutical Industry
AFR	Automatic fingerprint recognition
ANFO	Ammonium nitrate/fuel oil
BAC	Blood alcohol concentration
BMA	British Medical Association
BMK	Benzyl methyl ketone
BPA	Blood pattern analysis
BrAC	Breath alcohol concentration
CAP	Common approach path
CE	Capillary electrophoresis
CENTREX	Central Police Training and Development Agency
CJD	Criminal Justice Database
CPS	Crown Prosecution Service
CRFP	Council for Registration of Forensic Practitioners
Δ^8-THC	Δ^8-Tetrahydrocannabinol
Δ^9-THC	Δ^9-Tetrahydrocannabinol
EDX	Energy dispersive X-ray analysis
EMIT	Enzyme multiplied immunoassay technique
ESDA	Electrostatic deposition analysis
ESLA	Electrostatic lifting apparatus
FAAS	Flameless atomic absorption spectroscopy
FEL	Forensic Explosives Laboratory
FLP	Fragment length polymorphism
FOA	First Officer Attending
FSS	Forensic Science Service
FTIR	Fourier transform infrared spectroscopy
GC	Gas chromatography
GC-MS	Gas chromatography-mass spectrometry
HLA	Human lymphocyte antigenicity
HMX	Cyclotetramethylene tetranitramine

HOLMES	Home Office Large Major Enquiry System
HPLC	High-performance liquid chromatography
IAFS	International Association of Forensic Scientists
IC	Ion chromatography
ICP	Inductively coupled plasma spectroscopy
IEF	Isoelectric focusing
ILAC	International Laboratory Accreditation Cooperation
IR	Infrared analysis
LC-MS	Liquid chromatography-mass spectrometry
LGC	Laboratory of the Government Chemist
LMG	Leucomalachite green
LSD	Lysergic acid diethylamide
MDA	Methylenedioxyamphetamine
MDMA	Methylenedioxymethylamphetamine
MSP	Microspectophotometry
NAA	Neutron activation analysis
NAFIS	National Automated Fingerprint Identification Scheme
NTCSSCI	National Training Centre for Scientific Support to Crime and Investigation
PCR	Polymerase chain reaction
PETN	Pentaerythritol tetranitrate
PF	Procurator Fiscal
PGC	Pyrolysis gas chromatography
PGM	Phosphoglucomutase polymorphism
POLSA	Police Search Advisor
PSDB	Police Scientific Development Branch
RDX	Cyclotrimethylene trintramine
RFLP	Restriction fragment length polymorphism
RIA	Radioimmunoassay
SEM	Scanning electron microscope
SERRS	Surface enhanced resonance Raman scattering spectroscopy
SGM	Second generation matrix
SIT	Spontaneous ignition temperature
SLP	Single locus probe
SOCO	Scene of Crime Officer
SOP	Standard operating procedure
SSM	Scientific Support Manager
STR	Short tandem repeats
TIAFT	The International Association of Forensic Toxicologists
TLC	Thin-layer chromatography
TNT	2,4,6-trinitrotoluene
VNTR	Variable number tandem repeats

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CHAPTER 1

Forensic Science

BRIAN CADDY and PETER COBB

1.1 INTRODUCTION

Forensic scientists soon discover when talking to the general public that many people have an extremely limited knowledge of forensic science and the tasks it performs. As conversations continue it becomes apparent that misconstrued ideas often originate from watching television dramas. The material in this chapter is set out to address these misconceptions, by providing a definition of forensic science, a discussion of its origins and how forensic science services have been developed and operate within the United Kingdom. The duties of a forensic scientist and how the high standards of analysis and behaviour that are required are maintained also form an important aspect of this chapter.

1.1.1 Forensic Science – A Definition

If one were to ask one hundred forensic scientists to define forensic science it is possible that one would receive one hundred different definitions but it might be expected that amongst these there would be reference to science and the legal process. A useful working definition therefore is that "forensic science is science used for the purpose of the law". Consequently, any branch of science used in the resolution of legal disputes is forensic science. This broad definition covers criminal prosecutions in the widest sense including consumer and environmental protection, health and safety at work and civil proceedings such as breach of contract and negligence. However, in general usage the term is applied more narrowly to the use of science in the investigation of crime by the police and by the courts as evidence in resolving an issue in any subsequent trial. The narrower definition is implied in the title of this book and the following chapters will discuss the use of science in the investigation of offences such as murder, violent assault, robbery, arson, breaking and entering, fraud, motoring offences, illicit drugs and poisoning. Covering such a range is justification for restricting the definition in a work such as this.

Confusion sometimes exists in the mind of the public between forensic scientists and those involved in forensic medicine (the latter is sometimes referred to as legal medicine). The forensic scientist, as defined above, can be involved in all types of criminal investigation but forensic medicos restrict their activities to criminal and civil cases where a human body is involved. These are nearly always serious cases such as murder and rape *etc*. and will require the participation of pathologists and/or police surgeons.

1.1.2 An Historical Background

The origins of forensic science can be traced back to the 6th century with legal medicine being practised by the Chinese. Within the next ten centuries advances in both medical and scientific knowledge were to contribute to a considerable increase in the use of medical evidence in courts. Other types of scientific evidence did not start to evolve until the 18th and 19th centuries, a period during which much of our modern-day chemistry knowledge was just starting to be developed. Toxicology, the study of poisons, emerged as one of the new forensic disciplines, and was highlighted by the work of Orfila in 1840 with his investigation into the death of a Frenchman, Monsieur Lafarge. Following examination of the internal organs from the exhumed body, Orfila testified on the basis of chemical tests that these contained arsenic, which was not a contamination from his laboratory or the cemetery earth. This evidence resulted subsequently in Madame Lafarge being charged with the murder of her husband, but more importantly raised the problem of contamination, a constant concern for any forensic scientist.

During the latter part of the 19th century there was also considerable interest in trying to identify an individual. One approach, studied by Alphonse Bertillon, was to record and compare facial and limb measurements from individuals. This proved to be unsuccessful due to the difficulties in obtaining accurate measurements. However, this was the first recorded attempt in a criminal investigation to use a classification system based on scientific measurement. Interestingly and in accord with this principle, forensic scientists today use the results from a combination of analytical measurements to discriminate between groups or to compare samples.

A more successful development in personal identification was to come from fingerprint examinations. Although Bertillon is reported to have used latent fingerprints from a crime scene to solve a case, it was Sir William Herschel, a British civil servant in India, and Henry Faulds who were credited with performing most of the early investigations. Faulds, a Scottish physician, is also accredited with establishing the fact that fingerprints remain unchanged throughout the life of an individual. It was not until 1901, however, when Sir Edward Henry devised a fingerprint classification scheme for cataloguing and retrieving prints, that the full potential of personal identification through fingerprint evidence could be used in forensic investigations.

Body fluid samples have also been found to contain information that can help to identify an individual. The progress made in this area has been dramatic, and major advances have occurred within the past decade. Up until 1900 it had been impossible to determine if a blood sample or stain was of human or animal origin, or to classify human blood into four main groups: A, B, AB and O. When tests devised by Paul Uhlenhuth (blood origin) and Karl Landsteiner (blood groups) were used, discrimination between individuals was still poor. The inclusion of the Rhesus test and several different enzyme systems improved discrimination, but it has only been through recent studies of deoxyribonucleic acid (DNA) in human chromosomes that there have been dramatic improvements in the confidence of identifying an individual.

To Edmund Locard (1910) is attributed an important basic principle of forensic science, this in essence being that 'every contact leaves a trace'. Whilst the examination of fingerprints or body fluid, which might be present in only trace amounts, can directly implicate a particular person in a crime, other types of trace evidence *e.g.*, glass, paint, fire accelerants, gunshot residues, *etc.*, can provide links which establish contact between objects and/or people involved with a crime or present at a crime scene.

The ability nowadays to be able to analyse such a variety of materials stems from technological advances that have occurred particularly in the past 50 years. Many of the analytical techniques that have been devised offer unbelievable sensitivity and permit examination of minute quantities (traces) of material which cannot be observed directly by the human eye. To provide some indication of the amount of material being examined in these trace samples consider initially a grain of sugar. This can be seen without any difficulty and weighs about 1 milligram (1 mg; *i.e.*, one thousandth of a gram or 1×10^{-3} g). Now consider one millionth of this quantity which is 1 nanogram (1 ng or 1×10^{-9} g). This amount of sugar cannot be seen, but quantities as small as this can be detected by many analytical techniques. Even lower detection limits can be obtained routinely with some instrumental methods and although beneficial, extreme caution is required at every stage of any investigation and subsequent analysis to ensure a positive result is genuine and not due to contamination or any other artifact.

Rapid developments in computer technology have also played an important role in the advancement of forensic science. Apart from their use in controlling instruments and producing analytical data, computers permit the storage of massive amounts of information that can be searched very quickly. With computers has come the establishment of databases for DNA recovered from body fluids and sometimes tissues and hair, fingerprints and footwear marks *etc.*, the purpose of these particular ones being to help in the identification of an individual or items associated with an individual. These and other databases can save a tremendous amount of time and effort in a case and are beneficial to both the police in following their enquiries and the forensic scientists in providing evidence and information for the courts.

1.1.3 Forensic Science in the United Kingdom

Prior to specialist laboratories being established, the police in many parts of the world relied upon scientific assistance from people who, through their occupations, were able to provide the expertise required. Without a centralised system, knowing whom to approach was a problem and this resulted initially in the formation of formalised institutions, these being established almost invariably as parts of universities or hospitals. Since over time, these were restricted to examining and providing expertise in a limited number of forensic science disciplines, police forces took the step of developing their own forensic science laboratories.

Europe took the lead in this development with the first police forensic laboratory being opened in 1910 in Lyons, France. Thereafter, police laboratories were to appear in Germany (Dresden, 1915), Austria (Vienna, 1923) and other countries including Holland, Finland and Sweden, with these last three all coming into service in 1925. This transition did not occur in the United States of America (USA) until 1923 when the Los Angeles Police Department set up its own forensic science laboratory. The failure to obtain an indictment in a case due to improper handling of evidence prior to laboratory examination was the reason for this change. Many other Police Departments across America followed this lead with the Federal Bureau of Investigation (FBI) laboratory opening in 1932.

Interestingly, the first police forensic science laboratory in the United Kingdom was not established until 1935, when the Metropolitan Police Laboratory sited at Hendon was opened. How this laboratory started is a fascinating history. It all arose from the unofficial efforts of a constable, Cyril Cuthbertson, who was interested in medicine and criminalistics (in the United Kingdom this term is usually associated with the examination of physical evidence such as footwear marks but it has a much wider meaning in the USA and covers most of the activities undertaken in a forensic science laboratory) and became involved in applying scientific tests that helped his police colleagues in their investigations. Following his examination of a document and his attendance at court as a witness, praise for his testimony and skills soon filtered back to Scotland Yard. The Police Commissioner, Lord Trenchard, took a considerable interest in this matter as he could see the benefits of a laboratory dedicated to his police force. As a consequence he, over a period of time, persistantly engaged the Home Office over this matter and this eventually paid off.

The success of this laboratory resulted in the Home Office sanctioning the development of their own forensic laboratories, under the banner of the Home Office Forensic Science Service, to provide regional laboratories for police forces in all areas of England and Wales. These laboratories were all financed from central and local government funds until 1991 when the Forensic Science Service (FSS) became an executive agency of the Home Office. The agency comprises the five operational laboratories of the former Home Office Forensic Science Service (located in Birmingham, Chepstow, Chorley, Huntingdon and Wetherby) and, since 1996, the Metropolitan Police Forensic Science Laboratory in London. Wherever possible, facilities are provided locally but the corporate structure allows the concentration of specialist expertise in particular laboratories so that a comprehensive service is available.

Agency status enables the FSS to charge for the facilities offered on a contract, case by case or item by item basis depending on the circumstances. These facilities are also available to the defence in criminal cases. Where work is performed for both prosecution and defence the work from each is conducted at different laboratories and client confidentiality is maintained. Other agencies which were formerly part of government departments and offer forensic science facilities are the Laboratory of the Government Chemist (LGC), particularly in the area of drugs and documents, and DSTL, formerly the Defence Evaluation and Research Agency, operating under the Forensic Explosives Laboratory (FEL) in respect of explosives. Agency status allows the provision of services to any customer in the United Kingdom or overseas.

Forensic Science Northern Ireland in Belfast is also a government agency and provides forensic services to the province. In Scotland forensic science facilities are still provided by individual police forces with laboratories in Aberdeen, Dundee, Edinburgh, and Glasgow.

Although the laboratories referred to above can generally be regarded as the 'official' laboratories there is a wide range of practitioners and practices throughout the country providing an independent forensic service to clients. These include university departments, public analysts, large and small practices and sole practitioners. Although these may undertake prosecution work, they have a particular role in working with lawyers retained by a defendant in a criminal case to explore the strengths and weaknesses of scientific evidence tendered by the prosecution. Whilst this may include the laboratory examination of original or new material in a case it will usually involve an evaluation of the results obtained by the original scientist and the interpretation offered. The latter may require modification in the light of further information provided by the client or discovered by the retained expert.

Following the change to agency status the 'official' and private laboratories, together with other institutions, are all competing against each other for custom from the police or in offering a service for the defence. Unfortunately, although some of these laboratories have sought quality control and accreditation of their procedures and facilities, as described later in this chapter, there is no system of accreditation or regulation of the forensic science profession. This means that any organisation can now offer and supply forensic science services whether or not they have the technical competence and experience.

There are hidden dangers in a totally 'privatised' forensic science service any country might adopt. For example, commercial pressures and competition could lead to compromised standards. Constraints on budgets could also restrict both the amount of material submitted and the analytical work to be performed. The danger with this scenario is that these restrictions could prevent the forensic scientist from reaching a conclusion which might provide a court with either stronger evidence to support a prosecution, or show that the accused could not have perpetrated a criminal act. Therefore, it is essential that these dangers are identified and appropriate controls are put into place.

There has been one other development in forensic science, this being the introduction of civilians, called Scene of Crimes Officers (SOCOs) or Crime Scene Examiners, into police forces to carry out the searching of crime scenes and collection of evidence. Contrary to belief, it is nowadays quite rare for a forensic scientist to attend a scene and one reason for introducing SOCOs into the forensic system was to reduce the amount of time forensic scientists were being called away from their laboratory work.

Over the years there has become an increasing recognition of the importance of crime scene investigation and the need for collection, packaging and transport of material of potential evidential value. Whilst in earlier days this would have been carried out by a detective or a scientist, it is now usually performed by specialists who have received extensive training in all aspects of crime scene examination including latent fingerprints, evidential traces and photography. This professionalism should ensure that the integrity of items received by the scientist for examination cannot be disputed.

In conclusion the forensic science work performed in the United Kingdom has for many years been regarded very highly throughout the world for its integrity. The implications of any changes implemented, such as the change in status of the forensic laboratories, must be monitored and reviewed and actions taken where necessary to preserve the reputation of the service and more importantly, to ensure that it is not responsible for any miscarriage of justice.

1.2 WHEN IS FORENSIC SCIENCE REQUIRED?

A police officer investigating an incident will seek clarification of three issues:

1. Has a crime been committed?
2. If so, who is responsible?
3. If the responsible person has been traced is there enough evidence to charge the person and support a prosecution?

This clarification is seldom the isolated duty of one officer and the ultimate trial will reveal the involvement of the specialist police officers and civilian staff, lawyers and scientists. Forensic science can be expected to make a contribution to the clarification of all three issues.

1.2.1 Has a Crime Been Committed?

In most cases there may be no doubt that a crime has been committed but there are a number of occasions when only a scientific examination of items can inform the investigator that this is the case. For example, alleged possession of an illicit drug will require identification of the seized material. Similarly, to support an offence of driving under the influence of drink or drugs a blood sample taken from a motorist will require an accurate analysis not only to establish that alcohol or a drug is present but that any alcohol exceeds a permitted level. The presence of semen on a vaginal swab from an under-age girl will be evidence of illegal sexual activity. Similarly the demonstration of toxic levels of a poison in tissues removed at post-mortem from a body of an individual believed to have died from natural causes will be a strong indication of a crime. Doubts as to the authenticity of a document may be resolved by scientific examination and provide evidence of fraud.

1.2.2 Who is Responsible?

If a latent fingerprint is developed and recovered from a crime scene and the criminal's prints are already in a database then the person potentially responsible for that crime may soon be identified. Similarly the existence of a database of DNA profiles may enable identification of an offender who has bled at the scene of violence or who has left other body fluids in a sexual assault. Although specific identification of an offender may not be provided by scientific examination useful leads may be produced which will enable the investigator to reduce the field of enquiry.

1.2.3 Is the Suspect Responsible?

Irrespective of any support received from the scientist, the usual diligent police investigator often produces a suspect and the investigator will look to the scientist to provide corroborative evidence to enable a charge to be made and to assist the court in deciding guilt. The scientific examination will normally be directed towards two aspects:

1. Examination of material left on the victim or at the scene which is characteristic of the suspect.
2. Examination of the clothing and property of the suspect for the presence of material characteristic of the victim or the scene.

1.2.3.1 Materials Characteristic of the Suspect. The biological, physical or chemical characteristics of materials found on the victim or at the scene can help to confirm the identity of the suspect and/or provide evidence of their involvement or presence at the crime scene. Blood, semen, saliva, fingerprints, hair and teeth are all characteristics of an individual.

Finding fibres from clothing or the characteristic pattern of the soles of shoes worn by a suspect may provide evidence of their involvement, as can any material found that may be associated with their particular occupation. The characteristics of a vehicle, if used in the crime, such as oil drips or tyre marks may indicate where it had been parked or driven over ground near to or at the scene. Paint, glass or plastic from the vehicle after a collision may help to identify the particular vehicle and hence the owner who could become a suspect. Finally, the characteristic marks that may arise from weapons, tools or other items used in committing a crime, for example, a knife in a stabbing, a screwdriver used in forcing an entry or a firearm used in a robbery, especially if found on the suspect, could provide further evidence of a suspect's association with a crime.

Clearly it is very unlikely that all these possibilities will be realised in a single case but knowing the circumstances surrounding a case and taking into account previous experiences the forensic scientist should be in a position to exploit their skills to the benefit of the investigator and the courts.

1.2.3.2 Materials Characteristic of the Scene or Victim. The crime scene could be in a building or outdoors, but any search usually yields materials that are characteristic of the particular location as identified below:

1. Domestic premises – external and internal painting, external and internal glass, furnishings, crockery and glassware, *etc*.
2. Commercial premises – as for domestic plus process materials.
3. External scenes such as gardens, waste ground and fields – soil, vegetation and miscellaneous debris.

Where the scene involves a living or dead victim, biological and clothing characteristics discussed above for the suspect will also apply.

1.3 DUTIES OF THE FORENSIC SCIENTIST

Having established when the service of a forensic scientist could be required their duties can now be identified as follows:

1. Examine material collected or submitted in order to provide information previously unknown or to corroborate information already available.
2. Provide the results of any examination in a report that will enable the investigator to identify an offender or corroborate other evidence in order to facilitate the preparation of a case for presentation to a court.

3. Present written and/or verbal evidence to a court to enable it to reach an appropriate decision as to guilt or innocence.

Under the adversarial system of trial used in the United Kingdom, the United States of America and many other parts of the world the individual forensic scientist may be regarded as, and claimed to be, an independent witness for the court but may not always be so regarded. It is essential therefore for the scientist to be able to demonstrate competence, impartiality and integrity by attention to issues such as the following:

1. The scientist should only give evidence on work carried out personally or under their direct supervision. However, an expert witness can interpret factual evidence given by another witness under oath in the light of scientific findings and knowledge.
2. Where scientific examinations are relied on for legal purposes the methods used should be based on established scientific principles, validated and, preferably, published in reputable scientific literature, so that they can be scrutinised by the scientific community at large.
3. Where the scientific findings require interpretation the basis of any interpretation should be available to the scientific community.

It is important to recognise that the responsibilities of the individual forensic scientist are personal and not corporate. Thus in giving evidence he or she is completely and solely responsible for their own experimental results and for the opinions expressed. However the corporate environment will usually be a supportive structure to provide appropriate training, standardised methods and procedures, evaluation of performance and a quality management system. Attention to the last can be a real source of reassurance to the individual forensic scientist, the criminal justice system and the public at large.

1.4 QUALITY IN FORENSIC SCIENCE

There are many definitions of quality but for our purposes that of the International Organisation for Standardisation (ISO) is appropriate:

Quality: The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.
(ISO Standard 8402: 1986)

The ultimate 'customer' to be satisfied is the court and it will expect there to be in place a total quality management system that will ensure the integrity of material examined by the scientist, the examination carried out and the testimony given.

1.4.1 Quality at the Scene – Laboratory Chain

The quality control system must clearly extend outside the laboratory environment and places a responsibility on all involved in an investigation to maintain, as often specified, a chain of custody. A more appropriate expression would be a chain of integrity since the court will need to know not only the identity of the links in the chain but also their behaviour as illustrated in Table 1.1.

Even on this short consideration it can be noted that apart from knowing the identity of the 'custodians' of items at each stage, the court will need to be assured of their awareness of the consequences of any deficiency in the processes in which they are involved. For this reason in many investigations most of the process is conducted by specialist personnel with occasional assistance from laboratory based scientists. All involved will need to protect the items from the twin problems of deterioration and contamination. The latter is a vital matter when a suspect has been arrested since all possible contact between items from two sources must be prevented with proof that the appropriate actions have been taken.

Table 1.1 *The scene-laboratory links in the chain of custody to ensure quality in this procedure*

Link	*Category*	*Comment*
1	Preservation of the scene	This can be difficult in the early stages, particularly when injury or hazard is involved but the police must establish access control as soon as possible. Thereafter access must be restricted to those who can make a real contribution to the investigation.
2	Search for material of potential evidential value	This must be systematic with careful records kept of the location of all material collected.
3	Packaging and labelling of collected material	This must ensure that the material arrives at the laboratory as far as possible in the condition in which it is collected and that it can be related to the source.
4	Storage and transmission to the laboratory	Again preservation of the condition is a priority *e.g.* refrigeration may be appropriate.

1.4.2 Laboratory Quality Procedures

Clearly if the integrity of the articles received by the laboratory has been maintained the responsibility is then transferred to the scientist. The methods used for the examination of various evidential materials are detailed in subsequent chapters but certain principles apply to all examinations:

1. Prevention of contamination is a prime requirement, particularly as such small amounts of material can be examined and characterised. The scientist must be able to demonstrate that the procedures used have prevented the adventitious transfer of evidential material between two sources.
2. Security of all items must be assured by recording the name of all individuals having contact with them. This is usually achieved by signing an attached label but attention must always be directed towards the avoidance of leaving items unattended in the laboratory.
3. Careful permanent records should be kept at each stage of the laboratory examination to avoid any possibility of confusion by assigning results to the wrong item.
4. All the procedures and methods used by the scientist should be fully documented. These are often refered to as Standard Operational Procedures (SOPs) and Standard Methods (SMs). Forensic science laboratories normally have a comprehensive system detailing procedures to be followed and methods to be used. However, the final source of assurance is the competence and integrity of the individual.

1.5 ACCREDITATION OF FORENSIC SCIENCE FACILITIES

In common with many industrial organisations and scientific laboratories there is an increasing call for third party accreditation of forensic laboratories. In the United States of America this call has been met by the American Society of Crime Laboratory Directors through their Laboratory Accreditation Board. Under the auspices of this board the organisation, staffing and facilities of a laboratory are subjected to evaluation and on-site inspection before accreditation. A full re-inspection is carried out every five years. A good proportion of the many forensic science laboratories in the United States have been accredited by this process and some in other parts of the world especially Asia and Australia.

Given the smaller number of laboratories in the United Kingdom it has proved more convenient to use a well established system of accreditation applicable to all laboratories offering testing services to a client. The United Kingdom Accreditation Service (UKAS) is recognised by the government as the body for accrediting all types of laboratories and in this role has established a number of standards all of which have now been subsumed under two major standards namely ISO/IEC 17025 and ISO 9000:2000. The former is associated with laboratory tasks and some management aspects and the latter mainly with management issues. All these processes are being internationalised through the International Laboratory Accreditation Cooperation (ILAC) organisation. Clearly the wider recognition will be of great value to laboratories engaged in work supporting trade across international boundaries but given the increasing international nature of crime there must be attractions in the concept of all forensic laboratories working to a common high standard.

The accreditation process involves a series of steps. The applicant laboratory submits documentation, including its quality manual, to UKAS who then assign a Technical Officer and a Lead Assessor to be responsible for advising whether the laboratory should be accredited. This advice will be based on a pre-assessment visit for informal discussion and a broad review of the quality system followed by a formal inspection of the laboratory by an assessment team. At the end of the inspection the team will discuss any non-compliance found and agree the appropriate corrective action. If the assessment team are satisfied with the corrective actions UKAS will review all the evidence and decide whether to accredit. Following accreditation the laboratory will be subjected to regular surveillance and re-assessment visits to ensure that standards are being maintained.

A Forensic Science Working Group that took part in formulating standards for forensic science spent much time in defining what was meant by an objective test. Their definition is stated below:

An objective test is one which, having been documented and validated, is under control so that it can be demonstrated that all appropriately trained staff will obtain the same results within defined limits.

Objective tests are controlled by:

1. Documentation of the test.
2. Validation of the test.
3. Training and authorisation of staff.
4. Maintenance of equipment.

and where appropriate by:

1. Calibration of equipment.
2. Use of appropriate reference materials.
3. Provision of guidance for interpretation.
4. Checking of results.
5. Testing staff proficiency.
6. Recording of equipment/test performance.

The forensic scientist is required to tackle a wide variety of problems, many of which have no commercial analogue. This means that widely publicised and used methods such as those of the British Standards Institution may not be an option. The issues raised in the foregoing definition will assist the forensic scientist to develop the necessary degree of objectivity in the method applied to a particular problem.

1.6 PERSONAL ACCOUNTABILITY IN FORENSIC SCIENCE

The ultimate role of the forensic scientist is the presentation of expert testimony to the court trying the issue and in fulfilling this role the witness is completely and solely accountable for the experimental results presented and for the opinions expressed. These must be justified to the court, often in the face of fierce cross-examination and the witness cannot shelter behind the laboratory manual or base an opinion on a consensus or majority vote. This requires the witness to be a professional in the best sense of the word, that is, to have an initial developed competence which is continuously maintained together with a powerful sense of integrity. Clearly an employing organisation will have a responsibility in this respect but the public at large may seek the reassurance of membership of an independent professional body. The latter would seek to provide evidence of competence with a code of conduct and advice on professional behaviour.

This was recognised in recent times by a gathering of professional forensic scientists and although there is still no professional body for forensic scientists the outcome of their deliberations was the establishment, with government support, of a register of competent forensic scientists.

1.6.1 The Council for the Registration of Forensic Practitioners (CRFP)

Registration of forensic scientists with the CRFP is purely voluntary but since the scheme has the support of the government and the judiciary it is anticipated that the courts will expect, as a measure of their competence, that most forensic scientists will register.

In order to become registered a forensic scientist has to be assessed against a set of criteria that are identified below.

1. Knowing the hypothesis or question to be tested.
2. Establishing that items submitted are suitable for the requirements of the case.
3. Confirming that the correct type of examination has been selected.
4. Confirming that the examination has been carried out competently.
5. Recording, summarising and collating the results of the examination.
6. Interpreting the results in accordance with established scientific principles.
7. Considering alternative hypotheses.
8. Preparing a report on the findings.
9. Presenting oral evidence to court and at case conferences.
10. Ensuring that all documentation is fit for purpose.

The process requires that candidates submit brief details of a series of approximately 60 cases that they have investigated over the previous six months. An assessor will then select six cases from this list and request that the candidate submits full details of these cases in an anonymised form. Collectively these cases should enable the assessor to identify compliance with the ten criteria.

If the candidate meets the assessment criteria then he/she will be placed on the register in one of the defined areas as listed below:

1. Drugs – all areas of drug work not associated with toxicological investigations.
2. Firearms – ballistics, comparison microscopy and classification.
3. Human contact traces – DNA, body fluids, blood distribution, hairs and others (*e.g.* serology).
4. Incident reconstruction – fire and explosive investigation, metallurgy and material failures, traffic accident reconstruction, tyre examination, tachograph and non-metallurgic component failures.
5. Marks – tools, footwear, tyre marks, packaging and manufacturing marks and any others.
6. Particulates and other traces – fibres, glass, paint, explosive residues, gunshot residues, plant materials, pollutants, chemical traces and stains, any other particulate materials.

7. Questioned documents – handwriting, documents and other related materials.
8. Toxicology – toxicology, all aspects of alcohol analysis and interpretation.

Candidates are registered for four years before they are required to re-register. Re-registration requires the submission of information on continuous professional development and maintenance of professional competence. All those registered must comply with a code of conduct which is outlined below:

1. Recognise that your overriding duty is to the court and to the administration of justice: it is your duty to present your findings and evidence, whether written or oral, in a fair and impartial manner.
2. Act with honesty, integrity, objectivity and impartiality: you will not discriminate on grounds of race, beliefs, gender, language, sexual orientation, social status, age, lifestyle or political persuasion.
3. Comply with the code of conduct of any professional body of which you are a member.
4. Provide expert advice and evidence only within the limits of your professional competence and only when fit to do so.
5. Inform a suitable person or authority, in confidence where appropriate, if you have good grounds for believing there is a situation which may result in a miscarriage of justice.

In all aspects of your work as a provider of expert advice and evidence you must:

6. Take all reasonable steps to maintain and develop your professional competence, taking account of material research and developments within the relevant field and practising techniques of quality assurance.
7. Declare to your client, patient or employer if you have one, any prior involvement or personal interest which gives, or may give, rise to a conflict of interest, real or perceived; and act in such a case only with their explicit written consent.
8. Take all reasonable steps to ensure access to all available evidential materials which are relevant to the examinations requested; to establish, so far as reasonably practicable, whether any may have been compromised before coming into your possession; and to ensure their integrity and security are maintained whilst in your possession.
9. Accept responsibility for all work done under your supervision, direct or indirect.

10. Conduct all work in accordance with the established principles of your profession, using methods of proven validity and appropriate equipment and materials.
11. Make and retain full, contemporaneous, clear and accurate records of the examinations you conduct, your methods and your results, in sufficient detail for another forensic practitioner competent in the same area of work to review your work independently.
12. Report clearly, comprehensively and impartially, setting out or stating:

    (a) your terms of reference and the source of your instructions;
    (b) the material upon which you based your investigation and conclusions;
    (c) summaries of your and your team's work, results and conclusions;
    (d) any ways in which your investigations or conclusions were limited by external factors; especially if your access to relevant material was restricted; or if you believe unreasonable limitations on your time, or on the human, physical or financial resources available to you, have significantly compromised the quality of your work.
    (e) that you have carried out your work and prepared your report in accordance with this Code.

13. Reconsider and, if necessary, be prepared to change your conclusions, opinions or advice and to reinterpret your findings in the light of new information or new developments in the relevant field; and take the initiative in informing your client or employer promptly of any such change.
14. Preserve confidentiality unless:

    (a) the client or patient explicitly authorises you to disclose something;
    (b) a court or tribunal orders disclosure;
    (c) the law obliges disclosure; or
    (d) your overriding duty to the court and to the administration of justice demand disclosure.

15. Preserve legal professional privilege: only the client may waive this. It protects communications, oral and written, between professional legal advisers and their clients; and between those advisers and expert witnesses in connection with the giving of

legal advice, or in connection with, or in contemplation of, legal proceedings and for the purposes of those proceedings.

The introduction of the CRFP is a major step forward for the forensic science profession in the United Kingdom. However, the criteria used for registration are not standards in the accepted meaning.

1.6.2 Standards of Competence

Another body in the United Kingdom has been involved with drawing up standards of competence for forensic scientists, this being the Forensic Science Sector Committee of the Science Technology and Mathematics Council which is responsible to one of the new government Sector Skills Councils.

The standards are written in a generic form to enable all the different disciplines to be described. They are presented as a series of units with each unit being divided into a set of elements. The Units are listed in Table 1.2 and an example of one of the elements in Figure 1.1.

Having described standards of competence it then becomes necessary to develop a strategy for assessing scientists against such standards. Such assessment strategies are presently being developed.

Finally the United Kingdom has seen in recent years an enormous growth in undergraduate degrees in the forensic sciences and the quality

Table 1.2 *Professional standards of competence in forensic science*

Unit	*Element*
1. Prepare to Carry out Examination	1.1 Determine case requirements 1.2 Establish the integrity of items and samples 1.3 Inspect items and samples submitted for examination
2. Examine Items and Samples	2.1 Monitor and maintain integrity of items and samples 2.2 Identify and recover potential evidence 2.3 Determine examinations to be undertaken 2.4 Carry out examinations 2.5 Produce laboratory notes and records
3. Undertake Specialist Scene Examination	3.1 Establish the requirements for the investigation 3.2 Prepare to examine the scene of the incident 3.3 Examine the scene of the incident 3.4 Carry out site surveys and tests
4. Interpret Findings	4.1 Collate results of examinations 4.2 Interpret examination findings
5. Report Findings	5.1 Produce report 5.2 Participate in pre-trial consultation 5.3 Present oral evidence to courts and inquiries

You must ensure that you:	*You need to know and understand:*
a. make laboratory notes and records contemporaneously and that they are fit for purpose, accurate, legible, clear and unambiguous	1. why it is important to record information contemporaneously 2. why it is important to ensure that notes and records are fit for purpose, accurate, legible, clear and unambiguous
b. order notes and record information in a way which supports validation and interrogation	3. what information you need to record 4. which recording systems you need to use
c. uniquely classify records and file them securely in a manner which facilitates retrieval	5. when notes and records are complete 6. the systems you use to order your notes and record information
d. accurately collate laboratory notes on work carried out by others into the overall records	7. the importance of ordering notes and information 8. the classification systems you use to ensure records are easily retrievable 9. how the classification system operates 10. how to file records securely 11. the importance of collating notes accurately 12. the identity of others who might wish to use the notes 13. the ways in which the notes might be used

Figure 1.1 *An example of an element associated with standards of competence (from www.crfp.org.uk)*
UNIT 2: EXAMINE ITEMS AND SAMPLES
Element 2.5: Produce laboratory notes and records

of such degrees has been of concern to many in the profession. For this reason the Forensic Science Society has begun a programme of developing standards for such degrees that will be offered to the Universities as part of an accreditation programme. These are in the early stages of development at present but standards for crime scene investigation, laboratory analysis and interpretation and presentation of forensic science evidence are almost complete at the time of writing.

1.7 CONCLUSION

From what has preceded it is hoped that the reader will have an understanding of the role of the forensic scientist, how he/she achieves a professional status and how he/she interacts with the legal process. Working as a forensic scientist can be physically, emotionally and intellectually demanding but also intellectually rewarding. The succeeding chapters will show why this is so.

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CHAPTER 2

The Crime Scene

NORMAN WESTON

2.1 INTRODUCTION

Forensic evidence starts at the scene. If evidence is missed or incorrectly handled at the scene, no amount of laboratory analysis or processing will be able to rectify the problem and the scene usually cannot be revisited to have another attempt at obtaining additional evidence.

The people who bear the responsibility of examining the scene of any crime can include a police officer, a detective, a crime scene examiner, a scientific support officer or a forensic scientist. Historically, the person charged with investigating a crime has been prepared to consult those with specialist knowledge or professional skills who may add to, or account for, observations made at the scene of the crime. Throughout the 19th century, the level of technical support increased across a broad front, ranging from the increasing skills of the chemists in detecting poisons, to the introduction of photography, both for recording purposes and crime detection. This culminated in the first major work to recognise the significance of scientific approaches to crime detection with the publication in 1892 of *Criminal Investigation*, a book by Hans Gross which influences the art of crime detection to this day. Around the turn of the century the ability to both recognise an individual, and their involvement in crime, by the uniqueness of their fingerprints, outstripped all other developments in crime investigation. For the first time, evidence at the scene of a crime in the form of a fingermark, could be compared against a databank of known criminals and provide the investigator with a named individual.

The value of 'trace' or 'contact' evidence was, as previously stated, first recognised in 1910 when Edmund Locard introduced his theory of interchange. It is the finding, recovery, and scientific investigation of these traces which can provide the links in a chain of evidence, which are essential to assist the investigator. Unfortunately, in the early part of the 20th century, the ability to analyse minute traces of evidence by biological, physical or chemical techniques did not significantly exist. The great leap forward in analytical techniques and the electronic revolution in all branches of science has enabled Locard's trace evidence, whether blood, clothing fibres, glass, paint, soil from shoes *etc.*, from the scene of crime, to be matched with a suspect in such a way that it provides increasingly objective and significant evidence to link the suspect with the crime. In the case of DNA analysis from body fluid traces, this evidence approaches the same levels of certainty as fingerprint evidence and can also provide the name of an individual from a database. A further valuable evidence type has been provided by the consumer society's fascination with fashionable footwear and an infinite variety of patterned shoe soles. Particularly when worn or damaged, these can provide evidence of much greater significance than a plain leather sole. In parallel with these improving methods of analysis, many new techniques for developing and recovering evidence have become available, particularly in the recovery of fingerprints and shoe marks.

It is against this background of rapidly increasing technology that the crime scene is now examined. There is, therefore, a clear need that all who are required to deal with a crime scene should be trained to a high state of awareness, knowledge and skill. Increasingly, the solution of many crimes and particularly major crimes, depends on a thorough investigation of the crime scene by specialist crime scene examiners supported, when necessary, by other experts with scientific knowledge or expertise.

In practice, the time, effort or expense involved in crime scene investigation is tempered by considerations of the seriousness of the offence and the likelihood of recovering evidence of value which will identify the perpetrator of the crime. In this chapter, these constraints have been largely ignored and consideration has been given to what can be achieved. Two hypothetical cases have been used to illustrate the general principles of crime scene investigation and the actions of the scientific support personnel involved. Many different types of evidence can be gathered from crime scenes, but for the purpose of this text they are limited to those which are covered in some detail in the succeeding chapters. Furthermore, legal issues which influence the actions of police investigators and their scientific support staff will be referred to only in general terms.

2.2 THE ORGANISATION OF SCIENTIFIC SUPPORT WITHIN THE POLICE SERVICE OF ENGLAND AND WALES

Initially, scientific support in its various forms developed in a haphazard manner shadowing the techniques available. In the early part of the last century, there was a need for police officers with skills in photography, the development of latent fingermarks, the identification of fingermarks, and with some awareness of how to recover and deal with the other forms of forensic evidence likely to be found at the scene of crime. Their work expanded until, from the 1960s onwards, it was clearly necessary to form specialist departments to carry out this work. From the 1980s onwards, this led increasingly to the formation of Scientific Support Departments, which would encompass or have access to all the specialist areas likely to be needed in crime scene investigation and headed by a Scientific Support Manager (SSM).

At the same time, it was realised that as this work became specialised and technical, careers in scientific support would develop in their own right. There has been considerable variation in the way these have developed but the essential elements will be summarised.

2.2.1 The Fingerprint Bureau (Department)

This has grown out of the initial need for police officers to recover and photograph fingermarks at the crime scene, and then bring these back for comparison and identification. Increasingly, it became apparent that these officers could be most effective by specialising in fingerprint identification, leaving others to do the recovery. It was also realised that the skills of a trained police officer were not essential to do this work, and that concentration and pattern recognition skills were the most important. The large majority of Fingerprint Bureaux in the United Kingdom now employ a mainly civilian, *i.e.* non-police officer staff, specifically and intensively trained to identify fingermarks and to give evidence of identification in court, as fingerprint experts.

The introduction of the National Automated Fingerprint Identification System (NAFIS) has enabled fingerprint co-ordinates to be fed into a remote terminal and comparisons made with a centralised database. All on-screen identification comparisons are verified by fingerprint experts.

2.2.2 The Scene of Crime Department

The development of these units followed from the changes in the fingerprint departments. Advantages were seen in training officers who would develop increasing experience of all types of crime scene. Currently, these Scene Examiners assess the scene, control the scene, record the scene by document and photography, examine the scene and recover all types of evidence, interpret the scene from the evidence, collect and control the exhibits, liaise with all who are involved with the case and prepare reports and statements of evidence. The Scene of Crime Department is increasingly seen as able to advise on scientific matters and provide intelligence to link scenes or crimes together. At the scene they are the immediate source of advice on Health and Safety issues.

Again, this is a specialist career in its own right for which academic qualifications and technical skills in relevant areas may be more important than training as a police officer. Consequently, over 60% of Crime Scene Examiners in England and Wales are now non-police officers.

2.2.3 The Photographic Services Department

The duties of this department are less clearly defined. Variable amounts of photography are carried out in fingerprint and scene of crime departments as part of their normal duties. Many Forces employ specialist professional photographers to provide a service which can produce photographic and video images of the highest quality, especially when non-routine techniques are required. In addition, processing facilities are now required to provide a service in many other areas of police work, apart from the scientific support department's requirement. There is increasing use of photography in areas such as traffic, surveillance and public order offences. Photographers often form part of the scientific support team at major incidents and increasingly video recordings are made both for evidential purposes and as aids to "briefings". The increasing use of (electronic) imaging equipment and enhancement techniques is developing and changing the work of this department.

2.2.4 In-Force Laboratories and Scientific Services

In the early years, latent fingerprints were either photographed as they appeared, or enhanced by 'dusting' with powders and then photographed. Since that time, a wide range of techniques for the detection and enhancement of fingerprints have been developed world-wide. The problem of selecting the sequence of processes which are likely to be the most effective for the surface being examined has been solved largely by the work of the Home Office Police Scientific Development Branch (PSDB). This organisation has produced manuals and handbooks which give guidance using 'flow charts' on the best process for each circumstance. The pioneering work of the Serious Crime Unit (SCU) of the former Metropolitan Police Forensic Science Laboratory in London, with a shrewd combination of technical skills and serendipity, has developed the use of light sources including quasi lasers, lasers and photographic techniques to supplement chemical processes. The SCU has had notable success both in the laboratory and at scenes, as has the Specialist Fingerprint Unit (SFU) of the Birmingham Forensic Science Laboratory.

The success of these units has led to some police forces setting up their own laboratories to provide many of the more frequently used techniques both within their Force and at serious crime scenes. There is, however, still a need for the SCU and the SFU of the Forensic Science Service to support the Forces who lack these techniques, as well as providing the more sophisticated, or 'state of the art', techniques which can only be justified as a central service. Scientific Support Departments also examine shoe marks, tool marks and other 'physical' evidence which can be used to link offences or connect offenders. Increasingly,

Figure 2.1 *A crime scene examiner developing a latent fingerprint with aluminium powder*
(Courtesy of the Director of the National Training Centre for Scientific Support to Crime Investigation © NTCSSCI 1996)

Forces are developing their in-house technical and interpretational facilities as well as subjecting their staff to regular performance reviews, both to maintain and improve professional skills and competence.

2.2.5 Training & Information

Since 1990 and 1992 respectively, Crime Scene Examiners and Fingerprint Experts have been trained to approved 'National' standards at the National Training Centre for Scientific Support to Crime Investigation, based in Durham (N.B. now a part of 'CENTREX' – the Central Police Training & Development Authority). The Metropolitan Police in London see a particular need for a Crime Scene Examiner with enhanced skills in fingerprint examination and currently provide training for their own Fingerprint Experts/Identification Officers.

In many Forces, the 'Crime Scene Examiner' or 'Scene of Crime Officer' is taking an increasingly advisory and investigatory role in crime investigation using technical knowledge, crime intelligence databases and also by exercising their professional judgement. As this wider role is recognised, they may be increasingly referred to as 'Scientific Support Officers'.

In addition to specialised training, a valuable support and information service is provided by *Scenesafe Evidence Recovery Systems*. They make available a regularly updated *Scenes of Crime Handbook* in a handy pocket-sized format, and also other awareness material. In addition, they provide a comprehensive range of evidence recovery materials and containers which meet the requirements for subsequent scientific examination.

2.3 A BURGLARY: AN EXAMPLE OF A VOLUME CRIME SCENE

2.3.1 Case Circumstances

Cornelius Joseph Elliot, dressed in a track suit top and trousers, trainers and a woollen 'bobble' hat, had a small rucksack on his back containing the tools of his trade. He jogged down the road to create the impression that he was exercising. Elliot specialised in breaking into houses on housing estates where the majority of occupants were likely to be out during the day. On this day he selected one house where the rear was not overlooked, had high hedges and where there was a garden gate leading to a lane, thus providing an alternative way out of the back garden.

At the rear of the house, there was a kitchen window big enough to climb through. He pulled a dustbin into position, stood on the lid, and