


FORENSIC SCIENCE

FOURTH EDITION

ANDREW R.W. JACKSON
JULIE M. JACKSON



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FORENSIC SCIENCE

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4TH EDITION

ANDREW R.W. JACKSON
AND JULIE M. JACKSON

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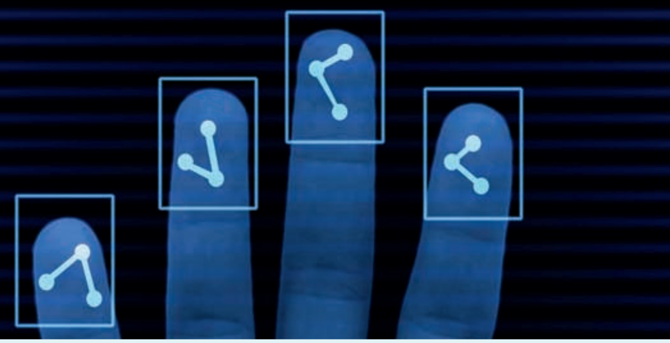

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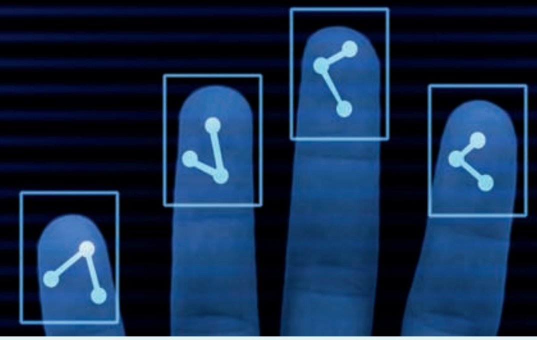

Welcome to the fourth edition of *Forensic Science*. The previous edition of this book was published in 2011. Since then, there have been significant changes in the organisation and accreditation of forensic science in the United Kingdom and the relevant parts of Chapters 1 and 2 have been revised accordingly. Also since the last edition of this book, in England and Wales, new procedures have been introduced concerning the reporting of the outcomes of forensic examinations. These new procedures, known as Streamlined Forensic Reporting, are described in Section 14.2 of Chapter 14.

Emerging three-dimensional imaging technologies that have the potential to change how crime scenes are recorded are introduced in a new section of Chapter 2 (see Section 2.3.4).

In recent years, there has been a recognition of the importance of minimising bias in the way in which forensic scientists establish in their minds the facts and opinions that they believe to be true. This recognition is reflected in this edition by the inclusion of material on minimising cognitive bias (Chapter 1, Box 1.1). The importance of contemporaneous note-taking in this and other regards is reflected in a new box on this topic (Chapter 14, Box 14.6). The ACE-V method can also provide safeguards against such bias and its use in the examination of fingermark evidence is explored in Box 4.1 of Chapter 4.

There have been developments in the field of DNA profiling, most notably the introduction of DNA17 – which is detailed in Chapter 6.

In different contexts, forensic scientists are asked to provide investigative leads and opinion based on evidence evaluation. These two roles require quite different ways of thinking. In Section 13.7 of Chapter 13, this new edition provides an account of logical frameworks that can help bring clarity to these contrasting thought processes.

There is now heightened concern about the use of chemical, biological, radiological and nuclear (CBRN) agents in criminal acts, including terrorism, and this is the subject of a new box in Chapter 11 (Box 11.1).

This new edition also includes worked examples of the application of the Bayesian approach to evidence evaluation (see Boxes 3.12 and 13.6 in Chapters 3 and 13, respectively).

Finally, this book is now in full colour, which we hope will enhance the reader's experience.

We hope that you enjoy reading this book and find it useful.

Andrew R.W. Jackson
Julie M. Jackson
June 2016

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Andrew R.W.
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Daniel Brearley
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CHAPTER 1
Introduction to forensic science

In its broadest sense, forensic science may be defined as any science that is used in the service of the justice system. Such a wide definition necessarily encompasses both civil disputes and criminal cases. However, in practice, forensic science is more likely to be involved in the investigation and resolution of criminal cases and it is with this aspect that this text is almost exclusively concerned.

This introductory chapter is designed to provide the reader with an insight into:

- **the role played by forensic science in the investigation of crime (Section 1.1);**
- **the scientific examination of forensic evidence (Section 1.2);**
- **the provision of forensic science services in the UK (Section 1.3);**
- **the accreditation of forensic science in the UK (Section 1.4);**
- **quality assurance within forensic science (Section 1.5).**

Through the topics covered, the reader is introduced to the discipline of forensic science in general and to this book in particular.

1.1 The role of forensic science in the investigation of crime

Forensic science plays a pivotal role in most criminal prosecutions, especially those of a more serious nature. Three distinct phases may be recognised within the progression from the collection of physical evidence to the presentation of scientific findings in court, each of which is described briefly in the following sections.

1.1.1 The recovery and continuity of evidence

The involvement of forensic science in the investigation and resolution of criminal offences begins at the crime scene. In this context, the term crime scene may be taken to mean any location, such as a building, garden or field, or person (whether alive or dead) that is to be searched for physical evidence.

Effective crime scene processing is the subject of Chapter 2 and is crucial to the ultimate success of any subsequent laboratory work. Furthermore, in any given case, it may prove pivotal in the solving of the crime.

A key part of successful crime scene processing is the identification and recovery of items of physical evidence. In the UK, this task is normally carried out by highly trained civilian specialists, usually known as Scenes of Crime Officers (SOCOs), Forensic Scene Investigators (FSIs) or Crime Scene Investigators (CSIs). However, under specific circumstances, other personnel may also recover evidence. These include police officers, who may, for example, take items of evidence from suspects, forensic medical examiners and forensic scientists. Once recovered, items of physical evidence must be separately and appropriately packaged, labelled, stored and transported to the laboratory (Chapter 2) for the next stage, that of forensic examination (Section 1.1.2).

It is vitally important that the integrity of each individual item of physical evidence is maintained from the point of its recovery at the crime scene through to its possible appearance as a court exhibit (Figure 1.1). Furthermore, it must be possible to demonstrate that this continuity of evidence has occurred. It is for this reason that, for each such item, records must be kept that show:

- the chronology of who has been responsible for its safekeeping and appropriate handling (the chain of custody);
- the measures taken to guard against evidence tampering, accidental contamination, deterioration and mislabelling (Table 1.1).

In addition, in serious incidents, the involvement of a dedicated exhibits officer will help to ensure continuity of the evidence.

Continuity of evidence
The provision of a complete documented account of the progress of an item of evidence since its recovery from a crime scene. If this cannot be adequately demonstrated, the evidence in question may be ruled inadmissible in court.

If **continuity of evidence** cannot be adequately demonstrated, then that evidence may be deemed inadmissible in court. This is because the loss of its integrity cannot be ruled out.

Not only is there an imperative to control the risk of the physical contamination of evidence, the risk of what is termed psychological contamination needs to be minimised too. In the forensic science context, psychological contamination is the introduction of unnecessary information into the mind of the practitioner which biases (i.e. skews) their findings. It is one of several types of mental phenomena, collectively known as cognitive bias, which can adversely impact on the findings of forensic scientists. Box 1.1 provides further information on these phenomena and actions that can be taken to minimise their impact.

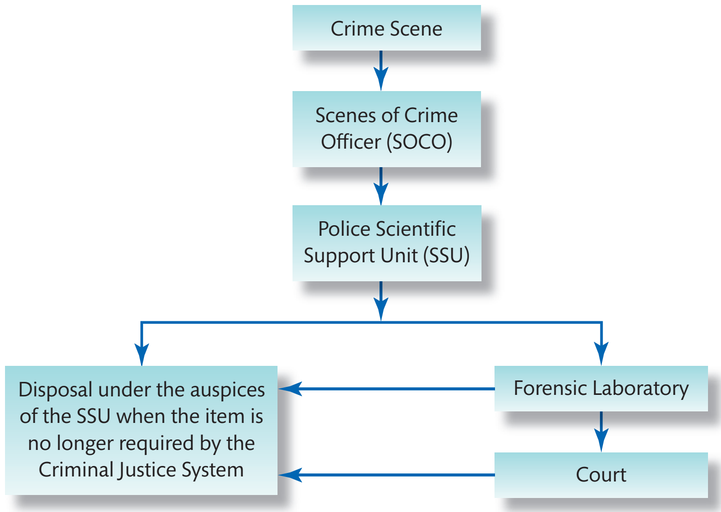

Figure 1.1 Typical route of an item recovered from a crime scene
Note that such items that are analysed in forensic laboratories are not often presented as exhibits in court. However, unless necessarily destroyed during analysis, any such item must be kept available in case it is needed in court. Where deemed appropriate, for any given item of evidence that has been recovered from a crime scene, one or more images of it may be presented in court instead of, or as well as, the item concerned

1.1.2 Laboratory work on physical evidence recovered from the crime scene

After items have been recovered from the crime scene, they are assessed for their potential evidential value. Those deemed to be of sufficient interest by the police are submitted to a laboratory for analysis. A range of organisations conduct such analysis at the request of the police. In England and Wales, these include the scientific support departments within the police forces themselves, large-scale commercial forensic providers (such as LGC Forensics, Cellmark Forensic Services, Key Forensic Services Ltd and the Environmental Scientifics Group) and small-scale forensic practitioners (see Section 1.3 for more details). In Scotland, crime scene processing, fingerprint work and laboratory-based forensic science are all undertaken by the Forensic Services section of the Scottish Police Authority. In Northern Ireland, Forensic Science Northern Ireland (part of the Department of Justice) conducts forensic scientific examinations for the Police Service of Northern Ireland.

Forensic analysis of items of physical evidence may provide answers to a number of important questions. In the first place, it may be necessary to establish whether a crime has indeed been committed. Perhaps surprisingly, this is not always immediately obvious. For example, consider a case in which a man is arrested and found to have packets of pale brown powder in his pockets, which he claims to be sugar. The police, however, suspect illegal possession of the drug heroin. In this particular example, identification of the packaged substance is key to determining whether a criminal offence has, in fact, taken place.

Table 1.1 Examples of measures taken to maintain and document evidence integrity

Mechanism of possible loss of integrity	Examples of measures taken
Tampering	• Tamper-evident seals on evidence packaging* • Use of dedicated, secure evidence storage facilities • Secure contemporaneous note taking (Box 14.6 in Chapter 14) • An uninterrupted, documented, chain of custody • Assiduous use of logging systems so, for example, the location of each item of evidence is known at all times • Minimising the number of people in the chain of custody • Opening packaging away from previous seals so that the integrity of those seals can still be seen

Accidental contamination	• Standard operating procedures (SOPs) that incorporate anti-contamination procedures, such as:
	  ◦ the isolation of bulk and trace evidence;
	  ◦ the use of appropriate personal protective equipment (such as hair and shoe coverings, gloves, masks and cover-all suits);
	  ◦ the decontamination of surfaces and/or people to guard against cross-contamination between samples;
	  ◦ the use of disposable equipment where appropriate to avoid between-sample cross-contamination;
	  ◦ the isolation of samples from victims and suspects and from different crime scenes associated with the same case
	• Appropriate use of negative controls (Section 1.2.1)
	• Re-packaging each item as soon as it has been analysed or examined
	• Minimising the need to open evidence packaging by, for example, the use of packaging that incorporates transparent panels so its contents can be seen
	• Assiduous use of logging systems and contemporaneous note taking to show compliance with anti-contamination SOPs

Deterioration	• Appropriate packaging and storage (see Section 2.4 in Chapter 2) • Assiduous use of logging systems and contemporaneous note taking to show use of appropriate packaging and storage
Accidental mislabelling of evidence	• The use of SOPs specifically designed to minimise the opportunity for mislabelling • The assiduous use of contemporaneous notes to demonstrate compliance with these SOPs

* Tamper-evident seals can take a number of forms. These include:

- specialist self-adhesive closures engineered into commercially produced evidence bags that, once closed, cannot be opened without obvious damage to the seal;
- signatures across seals in evidence packaging made using either conventional self-adhesive tape or specialist tamper-evident tape.

Much of forensic science is concerned with establishing whether any links exist between the suspect, victim and/or crime scene. According to Locard's exchange principle, 'every contact leaves a trace'. This means, in theory at least, that any physical contact between individuals, or between an individual and a place or object, invariably results

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Box 1.1 Minimising cognitive bias

Cognitive processes are those mental activities by which we each know what we know. It is ultimately by these means that all facts and opinions that we believe to be true are established in our minds. We form these beliefs in part by conscious reasoning and judgement, and in part by unconscious processes.

A bias is a skew that predisposes a process to produce a particular outcome. An incorrectly calibrated instrument might, for example, be responsible for blood alcohol determinations that were systematically low. If this were the only bias in the analytical processes concerned, this would produce an error. It would mean that too few people who were above the drink-drive limit would be found to be so. There would be a bias in favour of finding people to be below that limit.

Our cognitive processes are susceptible to bias, both conscious and unconscious. This too can lead to errors that could be as damaging to justice as bias caused by imperfections in analytical tests or by physical contamination.

There is more than one cause of cognitive bias and there is merit in recognising different categories of such bias as this helps in the development of approaches by which it can be minimised. However, this is not a particularly straightforward task and has resulted in categories that, in some instances, are very closely related to one another.

Categories that have been recognised include the following:

- *Anchoring effects* – when too much emphasis is given to a previously gained item of information (the anchor), thereby skewing later judgements as these are shaped to accommodate that anchor. For example, the knowledge that a particular vehicle was in the vicinity of a crime might lead investigators to subsequently explain other facts known about that crime so as to accommodate the involvement of that vehicle in its commission. This could cause better explanations to be ignored and would be an example of an anchoring effect.
- *Confirmation bias* occurs when a hypothesis is formed and the examiner then looks for evidence in support of it, rather than that which may refute it. For example, a scientist asking a colleague to 'verify a match' between two toolmark casts may influence that colleague to concentrate on those features present in both casts that are similar at the expense of any dissimilarities present.
- *Contextual bias* happens when extraneous information skews reasoning or judgement leading to a biased outcome. In a study published in 2006, Dror *et al.*[1] tested the susceptibility of five experienced fingerprint experts to contextual bias. For each expert, a pair of marks was selected. In each case, during their usual work and some years earlier, the expert concerned had classified the pair of marks as matching. Then, in their usual working environment, they were each asked by a colleague to examine the pair of marks concerned. They were told by that colleague that this was the pair of marks that the US Federal Bureau of Investigation (FBI) had wrongly assigned as matching and both originating from the Madrid bomber (Section 4.1.3 in Chapter 4). Three of the participants stated that the pair of marks that they then examined were a definite non-match, one stated that there was not enough information from the comparison to tell whether the marks matched and one stated that they did match. Thus four of the five experts in the study changed their judgement, indicating that they had been influenced by the extraneous information. The term psychological contamination has been used to describe the biasing of the findings of a forensic examination caused by the examiner's knowledge of extraneous contextual information.

[1] Dror, I. E., Charlton, D. and Péron, A. E. (2006) Contextual information renders experts vulnerable to making erroneous identifications, *Forensic Science International*, **156**, 74–78.

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- *Expectation bias* occurs when what one expects to find influences what is found. For example, consider a case in which it is known that a pair of shoes had been worn daily for three months and an examiner has been asked to comment on footwear marks that have been attributed to those shoes. This might unconsciously lead the examiner to find that the pattern of wear seen in the marks was as would be as anticipated from shoes worn daily for three months.
- *Reconstructive effects* happen when people use what they believe should have occurred to complete gaps in recalled memories. When work is normally carried out according to a standard operating procedure, as it must be in many areas of forensic science, there is therefore a natural predisposition to use that procedure to repair incomplete memory recall. This can therefore produce a cognitive bias.
- *Role effects* occur if the fact that an expert has been engaged by the police on the one hand or the defence on the other introduces a skew in the outcome of their work. Consider a case in which a screwdriver is believed to have been used to force open a window which has a painted wooden frame. In this hypothetical case, there was no paint found on the screwdriver. To interpret this lack of evidence of contact as neither telling for the prosecution or the defence could be to underplay its significance in favour of the defence's case. If such an interpretation by an expert had resulted from their perception of their role as being engaged by the police, this would be an example of cognitive bias caused by a role effect.

It is clear that humans are susceptible to cognitive bias. In the forensic context, arguably this is particularly so in evidence types that are analysed by qualitative means and/or in which there is some degree of ambiguity in the information relied on to draw conclusions.

Fortunately, as set out in draft guidance published by The Forensic Science Regulator[2] there are actions that can be taken to minimise the impact of cognitive bias in forensic science. A paraphrased summary of those actions identified in that guidance is provided below.

- Develop systems that:
  - utilise suitably experienced personnel to develop, for each case, a suitable forensic strategy based on all relevant information that is available;
  - allow for the examination of items of evidence (i.e. exhibits) in accordance with this strategy;
  - ensure that the analysts who carry out such examinations are only supplied with the necessary relevant information (i.e., as far as practicable, they work blind), thereby controlling contextual bias;
  - allow the review and interpretation of the results of those examinations to be conducted in the full case context whilst accepting the analyst's conclusions;
  - ensure that key aspects of the work are checked and that those checking the work of others are unaware of:
    - the initial findings of that work, thereby avoiding confirmation bias in these checks;
    - whose work is being checked (if possible to do so).
- Using a structured approach that provides rules that predetermine the order in which the work should be done, thereby guarding against confirmation bias. This is achieved by ensuring that the results of the examination of materials (such as the comparison of handwriting samples) are not influenced by the outcome of the assessment and evaluation of the meaning of those results (in our example, whether the samples are written by the same person). Examples of such structured approaches are the ACE-V method used for fingermark–fingerprint comparisons (Box 4.1 in Chapter 4) and the Case Assessment and Interpretation (CAI) model (Section 13.6.2 in Chapter 13).
- Assessment of the risk of cognitive bias and mitigating these risks is an integral part of method development. Thus, for example, it might be decided that the analyst should not deal directly with the investigating

[2] Sullivan, K. (2014) *Draft guidance: Cognitive bias effects relevant to forensic science examinations.* Birmingham: The Forensic Science Regulator.

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officer in order to manage the flow of information and thereby mitigate the risk of contextual bias.

- Provide cognitive bias awareness training to the relevant personnel.
- Consider incorporating cognitive bias susceptibility testing as part of the procedures for the recruitment of new staff (not all people are equally vulnerable to the problem of cognitive bias).
- Use regular competency testing to ensure that staff are able to perform at an appropriate level.
- Keep contemporaneous notes to guard against reconstructive effects (Box 14.6 in Chapter 14).
- Minimise the risk of role effects by:
  - ensuring that, as stipulated by ISO 17025, there are systems in place to shield staff from pressures (such as financial or commercial considerations) that might produce subconscious bias;
  - compliance with Criminal Procedure Rule 33.2 (Box 14.7) and those parts of the Forensic Science Regulator's codes[3] concerning the management of threats to the impartiality of forensic practitioners (Section 7.2 of those codes) and the duty and actions of those practitioners;
  - adoption of approaches, such as the previously mentioned CAI, that formally require that proper consideration is given to the propositions of each of the prosecution and the defence.

[3] Rennison, A. (2011) *Codes of Practice and Conduct for forensic science providers and practitioners in the Criminal Justice System*. Birmingham: The Forensic Science Regulator.

in the transference of traces of physical evidence. Examples of **trace evidence** that may be transferred in this manner include hairs, fibres, glass fragments, body fluids and gunshot residues. A comparison between similar items of trace evidence recovered from two different locations may establish whether there is a connection between the two. For example, it may help to place a suspect at the scene of a particular crime (although this does not necessarily mean that the said individual was involved in the commission of that crime). Evidence that links two separate entities, be they people or objects, can be termed associative evidence.

Trace evidence
Minute amounts of materials (such as glass shards, paint chips, hairs or fibres) that, through transference between individuals, between an individual and a physical location or between two such locations, may constitute important forensic evidence.

In many cases, forensic science can provide information that either corroborates or refutes evidence from another source, such as supplied by eyewitnesses to a particular event. Furthermore, forensic evidence can facilitate intelligence gathering by the police (Section 1.2.3). In the case of drugs, for example, the analysis of samples recovered from different locations may show that they have come from the same batch, or may help to pinpoint their country of origin (Chapter 7, Section 7.5.1). Forensic evidence may also reveal when an event occurred, or the order of a sequence of events. For example, it may be possible to determine the order in which two bullets struck a pane of glass (Chapter 3, Section 3.2).

Finally, the forensic analysis of particular types of evidence may help to establish the identity of an individual suspected of committing a crime. In cases where body fluids, such as blood or semen, are recovered from a crime scene, personal identification may be made through DNA profiling (Chapter 6). Similarly, a comparison of fingermarks left at a crime scene with fingerprints stored on IDENT1 (the UK's national database for fingerprints, palm prints and crime scene marks) may be successful in identifying the individual responsible (Chapter 4, Section 4.1.3).

1.1.3 The interpretation and evaluation of scientific evidence and the presentation of scientific test results in court

Once an item of evidence has been analysed, the scientist can interpret the results to ascertain what may be established about the nature of that item. Furthermore, he or she may evaluate the data obtained to establish whether it supports the proposition put forward by the prosecution or that proposed by the defence. These are matters that are explored in Chapter 13.

In recent years, a system known as Streamlined Forensic Reporting (SFR) has been introduced in England and Wales. As described in Chapter 14 (Section 14.2) this is a multi-step process that uses standardised forms to report the outcomes of crime scene processing and lab-based forensic science to the police, defence, prosecution and courts. In a given complex case, and/or when the scientific methods used are novel, the forensic scientist may be required to write up his or her findings in the form of a full evaluative statement for use in court. As well as being comprehensive, the contents of such a statement should be readily understood by non-scientists within the Criminal Justice System.

The majority of forensic science is undertaken by scientists engaged by the police. However, in cases that progress to court, the defence may also instruct independent experts of their own to examine the scientific evidence (Chapter 14, Sections 14.2 and 14.3).

In some cases, the forensic scientist is required to appear in court as an expert witness. In this capacity, he or she will give testimony of fact, and of opinion based on fact when required to do so, from within his or her own area of expertise (Chapter 14, Section 14.3).

1.2 The scientific examination of forensic evidence

After their recovery from a crime scene, items of potential forensic importance are sent to the laboratory for scientific examination. This is done to obtain information relevant to the case in question from the articles submitted. The type of approach used for any given piece of evidence and its evaluation will be determined by the type of information sought.

An important distinction is that between qualitative analysis and quantitative analysis. The former is concerned with information that can provide evidence about the identity of an entity, while the latter aims to establish the amount or concentration of a given substance. For example, qualitative analysis may establish whether a given sample of blood contains alcohol, but quantitative analysis will be required to determine whether the sample has an alcohol content that is above the legal limit for drink-driving (Chapter 7, Section 7.2).

Another important distinction should be drawn between whether the purpose of the examination is to provide intelligence (see Section 1.2.3) or to evaluate the strength of evidence for use in court (see also Chapter 13, Section 13.7).

1.2.1 The comparison of evidence

In the majority of cases, the scientific investigation of evidence will involve comparison. This may be performed in a number of different ways, each of which is discussed briefly below.

Comparison between an evidential object and a relevant database

In some instances, the purpose of this type of comparison is to identify a category to which an item of evidence belongs. To achieve this, the **class characteristics** of the evidential item concerned are established. For example, if footwear impressions or prints are recovered from a crime scene, their sole patterns may be established and then these may be usefully compared with sole patterns held on a footwear database (Chapter 4, Section 4.2.2). Through this exercise, it may be possible to identify the manufacturer and, conceivably, the model of the shoe concerned. This type of footwear comparison is particularly relevant to trainers. Similarly, tyre marks left at an incident scene may be compared with an appropriate database of tread pattern designs.

Class characteristics
Characteristics that enable an object to be placed into a particular category, for example identifying a trainer as belonging to a certain brand.

With some specific types of forensic evidence, namely fingermarks and samples of body fluids or tissues used for DNA profiling, the object of comparison with a database is the identification of the individual concerned. In the case of fingermarks, this may be achieved by searching IDENT1 (the national database for fingerprints, palm prints and crime scene marks) for possible matches (Chapter 4, Section 4.1.3). With similar intent, DNA profiles may be compared with those held on the National DNA Database® (NDNAD) (Chapter 6, Section 6.3.6).

Comparison between two pieces of evidence obtained from different places

This type of comparison seeks to determine whether two pieces of apparently similar forensic evidence, for example hairs, textile fibres, paint chips or glass fragments, may share a common origin. Its purpose, therefore, is to determine whether any possible link exists between the two separate locations from which the evidence has been retrieved (Section 1.1.2). This may be between two individuals (as in the case of the victim of an attack and his or her assailant), between an individual and a crime scene, or even between two different crime scenes. This type of comparison may be usefully illustrated by the following hypothetical scenario.

Consider a case in which a car window is broken and a valuable item is stolen from the vehicle. A suspect is apprehended by the police and, although the item is not in the suspect's possession, there are fragments of glass adhered to the right-hand cuff of his jacket. A comparison is made between shards of glass taken from the car window and those recovered from the suspect. If these samples are found to be indistinguishable, this provides evidence that is consistent with the suspect being at the crime scene.

An exploration of how the strength of such evidence may be established is provided in Section 3.7 of Chapter 3.

Comparison between questioned samples, both positive and negative controls, and reference collections

A crime scene sample that is to be tested to find its evidential value is usually referred to as a questioned sample (or sometimes a disputed sample). Such tests are designed to evaluate a hypothesis. A hypothesis is a supposition that is either true or false and that can be tested by experimentation. For example, if a suspect is detained and found to possess a packet containing a pale brown powder, then the hypothesis may be that the powder is heroin. In order to test this hypothesis, experiments may be carried out that compare the chemical characteristics of this questioned sample with those of a known sample of heroin. Known samples such as this are referred to as positive controls, knowns or standards. If the questioned sample and the positive control are shown to