Understanding the Role of Forensic DNA: A Primer for Criminologists

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KEY TERMS

Adventitious Match: A chance match between profiles that do not originate from the same source.
Bayes Theorem: A logical method of weighing different pieces of evidence.
Buccal Swab: A sample of cells taken from the inside of a person's cheek using a swab.
Cold Cases: Those cases which have remained unsolved but open for many years.
Cold Hit: A DNA match which identifies an individual not previously suspected of involvement in a crime.
DNA Profile: A report produced after analysis of a sample of genetic material retrieved either from an individual or from a crime scene exhibit.
Ethnic Interfacing: Trying to predict an offender's ethnic background from his or her DNA profile.
Hypervariable Regions: Those regions of a DNA profile that vary greatly between individuals.
Prosecutor's Fallacy: A misconception committed whenever the recipient of statistical evidence, upon hearing it, believes that he or she has been told the likelihood of guilt or innocence.
Warm Hit: A DNA match which confirms the correct person has been arrested.

INTRODUCTION

It is now a number of years since it was commented that forensic DNA profiling was an "incredible part" of the criminal justice system of England and Wales: a claim that now may easily be made of the majority of the legal systems of developed nations. It may also be convincingly argued that the introduction of DNA profiling into forensic fora has been nothing short of revolutionary, leading to significant legal reform and changes to policing and prosecutorial policy and practice, at the same time as becoming culturally imbued with almost oracle-like qualities. Perhaps most importantly, the use of forensic DNA profiling has undoubtedly saved lives; potential victims not being imprisoned who have been stopped in their criminal tracks, as well as those imprisoned and on death row, exonerated when their innocence was no longer deniable after DNA testing.

In this chapter, the use of DNA in criminal justice matters, and the impact of DNA on the police and courts, will be explored. Those interested in the science behind DNA profiling should read scientific explanations of the process, which will not be covered in any detail here. This chapter relies primarily on data from England and Wales with international comparisons where available and relevant. The United Kingdom is widely considered as leading the international community in the use of forensic DNA and has the largest proportion of its citizenry on the UK National DNA Database (NDNAD). While the chapter concentrates on the utilisation of forensic DNA, it will not be possible to guarantee coverage of all possible issues, particularly where a country's size, culture, history, or legal system, for instance, differs significantly from the UK.

FORENSIC DNA ORIGINS

On September 10, 1984, Professor Alec Jeffreys and his team of genetic researchers at Leicester University produced what looked like nothing more than a murky barcode. However, Jeffreys realized that this "barcode" could be used as an identification tool for living organisms—much like barcodes identify the goods on our supermarket shelves. The production of these barcodes was given the moniker "genetic fingerprinting." Such a label was apt for a number of reasons, but importantly, it was able to piggy-back on the trust placed in fingerprinting as an identification technique. This label also made it significantly easier to explain to the layman, and it was non-scientists who quickly seized on its usefulness in being able to prove (or disprove) the relatedness of humans. It was this ability—to support claims of biological relationships—that was first put to the test by the authorities who called upon the Leicester laboratory to prove a biological (maternal) link in a disputed immigration case.

After this successful application, the technique continued to be called upon by the Home Office to assist in immigration disputes until in 1985, there were a series of rapes near Leicester, with a local youth confessing. An astute police officer, hearing of Jeffreys's work, realized that they could "test" this confession by comparing the genetic fingerprint of the young man and that of the rapist. The team at Leicester were able to conclusively demonstrate that the youth was, in fact, not the rapist. However, they were unable to assist further without the
DNA of a suspect, prompting Leicester police to set up the first "mass screen" of men in the local area. Though conscientiously and laboriously profiling all these samples, the screen was ultimately fruitless, until it was revealed to the police that a local baker had persuaded a colleague to provide a DNA sample on his behalf. The baker, Colin Pitchfork, immediately became a suspect and had his DNA taken, which matched the crime scene DNA and led to the first criminal conviction using a genetic fingerprint.

Sir Jeffery's genetic fingerprinting was soon refined and improved upon, developing into the technique known today as DNA profiling (Fobbing and Gill, 2004). A DNA profile is produced after analysis of a sample of genetic material retrieved either from an individual (usually a buccal swab or cheek swab) or from a crime scene exhibit. In 1995, the Second Generation Multiplex (SGM) profiling kit was introduced in the UK, using 6 loci and a gender marker, giving a random match probability for two full profiles, of 1 in 50 million. In 1999, a new improved kit was rolled out: the SGM+ system, which had an additional 10 loci. The SGM+ profiling technique produces a more discriminating profile, giving a random match probability of around 1 in a billion. Countries will vary in their use of proprietary DNA profiling kits; for example, in the United States, they test for 13 loci. The size of the population of the United States demands the use of more loci to make their test even more discriminating.

A forensic DNA profile loaded onto the UK's National DNA Database (NDNAD) will then consist of a series of 20 two-digit numbers and the gender indicator. These numbers represent the peaks noted at the different loci tested using the SGM+ kit, making searching for DNA matches a simple matter of comparing one set of 20 numbers with all the others on the database and seeing which sequences, if any, match. However, the ease of such a computational task belies the actual complexity often involved in actually deciding whether a peak is real or over a chosen threshold, matters of judgment which are complicated by partial or degraded profiles and profiles that are a mixture of more than one individual.

DNA profiling does not examine every single difference between individuals and so can only ever provide probabilistic evidence, though this can be very powerful if it reaches the 1 in 1 billion random match probability. The profiling process simply looks for these 10 loci which are hypervariable (also known as hypervariable regions, which vary a great deal between individuals) and also give no indication of anything else such as health information. Matches involving partial profiles (where the DNA sample retrieved may be degraded or only a tiny amount was available) or biological relatives are more likely to occur by chance, reducing discriminating power considerably. A chance match between profiles that do not originate from the same source is called an adventitious match. To date, there has been one reported adventitious match on the UK's NDNAD with two full SGM profiles.

For a consideration of the potential issues arising from greater reliance upon DNA during police investigations, see also McCaffrey (2006a).

There have been none (that have been reported) with SGM+ profiles, but the risk of adventitious matches inevitably increases as a DNA database grows.

**THE FORENSIC DNA "REVOLUTION" IN POLICING**

The precision of DNA profiling has made it very attractive to police investigators as a source of incontrovertible evidence. This is a welcome contrast with other, less reliable, evidence such as eyewitness accounts and information from increasingly uncooperative members of the public. DNA is impartial, scientific evidence (it is also increasingly cheap and quick). Indeed, even a decade ago, it was claimed that DNA "has not merely enhanced existing police capacity, but has even begun to replace the slow, tedious, and expensive traditional investigative methods of police interviews" (Watson, 1999, p. 325). In 2004, the British Home Office claimed that not only did science and technology "play a vital role in modern policing," but the National DNA Database was "revolutionizing" crime detection (Home Office, 2004).

It is hard to underestimate the scale of this revolution in the use of forensic DNA. There is now rarely a police investigation in which the question would not be asked whether DNA could play a role. Indeed, in the United Kingdom, as with many countries, the taking of DNA from individuals by the police is considered routine. While essential in major investigations into violent/sexual crimes, DNA also has significant impact in the investigation of volume (largely property) crime. Periodic initiatives focus on maximizing the use and usefulness of DNA in ever-increasing numbers and types of criminal investigations, the result of a combination of scientific/technological development and significant law reform, as well as substantial government financial investment.

This chapter will review the legal reforms that have enabled the use of DNA in criminal investigations and prosecutions and attempts to gauge the impact of DNA in the criminal process. It will go on to look at the growth of DNA databases before turning to issues that are increasingly coming to the fore, including the issue of the international exchange of DNA data, the raising of ethical questions, and the stretching of the science of DNA profiling.

**HOW DNA PROFILES ARE UTILIZED**

**In Police Investigations**

While the England, Wales, and Northern Ireland police have the widest powers in the world to obtain, and retain, DNA from suspects, victims, or witnesses in criminal investigations (though perhaps not for much longer), powers to take DNA from suspects and convicted offenders have been written into law in countries across the world. Many countries limit these police powers with
regard to the severity of the offense, but while the powers and nomenclature may vary, in general, the police obtain and retain three types of samples:

- Criminal justice or suspect samples—samples taken from individuals who have been arrested;
- Elimination samples—victim/volunteer samples;
- Crime scene samples—samples retrieved from crime scenes and crime scene exhibits.

When a DNA sample is taken, it is immediately subject to a "speculative search"—that is, the DNA profile, once obtained from the sample in the laboratory, is checked against all the DNA profiles already held on a DNA database, including those obtained from scenes of unsolved crimes and all the other DNA profiles held of individuals, checking for duplication. Any matches between newly loaded profiles and retained profiles are then reported to the police who submitted the sample for analysis for further investigation. A match report may not include just one individual; it is not unusual for the police to get a list of named suspects who may have left the DNA sample (or the matches are with replicates on the database). This is more likely where advanced searching or profiling techniques have been used.

The use of scientific investigative methods provides an opportunity to move away from reliance upon less reliable evidence, such as eyewitnesses, confessions, etc. The use of DNA also provides an opportunity to speed up investigations (saving time, money, and resources which can be spent elsewhere) and provide police intelligence where there may be none (or very little) to be garnered using more traditional policing methods. Crimes may be solved years after they occurred (so-called cold cases)—or linked together so offenders may be prosecuted for a series of offenses. While the causes of crime are multifaceted and complex, it is accepted that the chances of detection can act (in some cases) as a deterrent. There is then an argument that in time, if most people had their DNA retained by the police, crime would fall because not only would offenders be caught more reliably (and their criminal careers shortened), but other potential offenders would be deterred as they would know the certainty of being caught.

DNA located at a crime scene (or found on a weapon or victim, for example) is very powerful evidence. In some cases it can provide almost incontrovertible "proof" of identity. In rape cases, if there is a full sample left, then the issue of identity is almost undisputable; of course, it does not prove rape, which has further legal elements which require satisfying. Likewise, if a weapon used in a crime is located and DNA found on the weapon, then this will be highly suggestive of involvement with the offense. However, in some instances, the power of DNA lies in being able to exculpate an innocent suspect before locating (sometimes) the real perpetrator. In hundreds of cases, mostly in the United States, exculpatory DNA has not been tested until many years after the innocent individual has been in prison—sometimes even on death row. There has been significant (but incomplete) legal reform in the United States to now expedite the use of DNA to exonerate innocent citizens who remain in prison; in many cases, the real perpetrator has also been identified by such testing.6

In the United Kingdom, in over 42% of cases, DNA did not provide a fresh lead (or intelligence)—as the police already had the name of the suspect (and may have had him or her in custody) (Home Office, 2005). Essentially, the DNA match did not then detect the crime, but confirmed the correct person had been arrested and may prove useful in securing his or her conviction. These are sometimes referred to as warm hits, as opposed to cold hits where the DNA matches with an individual not previously suspected of involvement. The detection rate in which a DNA profile is obtained in connection with a crime is significantly higher—rising to 43% rather than the 26% overall crime detection rate—although it is rare, of course, that the police find DNA in all (or even most) cases, largely because they tend not to look for it too hard (which is costly and timely) rather than because it is not there. Perhaps contrary to expectations, DNA has proven most useful in those crimes that are the most difficult to detect—that is, domestic burglary, rather than the crimes that are the most serious (which tend to have a higher detection rate). For example, the overall detection rate for domestic burglary in England and Wales is 17%, but where DNA is retrieved from a crime scene, this rises to 39%, while theft from a car rises from 9% to 60% (Lake, 2006–2007, p. 16). Similar findings have been recently reported in the United States (Roman et al., 2008).

The success of DNA profiling is determined by the number of samples from crime scenes that can be subsequently linked with a perpetrator. Yet in the United Kingdom, there is wide variation between police forces as to the number of scenes examined, with approximately 12% of all known crime scenes examined, and DNA recovered from just 10% of these examined scenes, while the number of DNA samples sent to forensic laboratories for processing also varies. The reason for this primarily has to do with prioritizing necessary when working with limited budgets. In addition, in many crimes there will be no "scene" or exhibits to examine. Or it will be impossible to search effectively, or the culprit will be obvious. In England and Wales in 2007–2008, just 0.36% of recorded crimes were detected using DNA. This, of course, is an even smaller proportion of all crimes committed (of which only a minority are recorded), meaning that DNA still has a way to go before making a significant impact on crime as a whole. Of course, it can be very helpful in serious crimes, those with no other leads, and those where there was no other hope of detection—but as a general picture of "crime" and its detection, it remains marginal (and still used less often than the humble fingerprint). The most effective way of catching criminals remains asking the public for information. Whether or not they
assist the police is an issue of police-community relations. Yet increasing police powers to take and keep DNA may not foster the sort of police-community relations necessary to ensure public cooperation in investigations.

DNA databases are often referred to as a police “intelligence tool”—in that it provides investigators with “intelligence” about offenders and offences, including offender patterns. It is an incredibly powerful resource with new methods continually being developed to further utilize the information stored therein. Two methods include familial searching and ethnic inferencing—(trying to predict an offender’s ethnic background from his or her DNA profile; see later). The police can also trace the offending patterns of unknown profiles—serial offenders who are evading arrest and may be traveling around a country or jurisdiction committing crimes that are not linked by police forces.

The use of DNA requires different policing skills, and lack of training remains a significant issue. In reality, most regular personnel do, most regular police officers will rarely, if ever, be involved in a crime that requires them to deal with DNA, meaning that if they do, many are ill prepared. It is essential that all police (and emergency services personnel) are forensically aware if DNA is to be successfully obtained and contamination avoided. There are significant issues with the collection of DNA which, if done incorrectly, cannot then be salvaged later (such as in the Duke lacrosse case in the United States). There is no room for error—in the laboratory, but importantly, also at the crime scene. DNA profiling is a sensitive technique, and without the investment of time and resources in proper and thorough crime scene examination, DNA will remain marginal; if not problematic, in police investigations.

**Pretrial Issues**

The presence of DNA as a crime scene cannot constitute proof of guilt for any crime on its own. In England and Wales, a DNA match is not sufficient evidence upon which to base a criminal charge. Supporting non-DNA evidence must also be submitted to the Crown Prosecution Service (CPS) before they decide to proceed with charging. Most often, a DNA match will lead to further investigations being undertaken by the police, to confirm the match. However, what counts as supporting evidence is a matter for the CPS lawyer, and there is no uniformity in this decision. In some cases, being arrested “close to the scene” is sufficient, or being male and a smoker has been sufficient (with previous convictions). Increasingly, a strong DNA match can be supported by quite weak additional evidence (i.e., lack of an alibi).

In some cases, a DNA match will be very persuasive evidence: for example, in a stranger rape, if a suspect matches the DNA sample and cannot offer an explanation (or produce an alibi), for example, then this will almost inevitably lead to a conviction (most likely from a guilty plea). However, all DNA matches have to be interpreted within the case—a match may not actually mean very much. If a woman is killed in her home, and her husband’s DNA is found, that DNA is not going to provide evidence because one would expect to find the husband’s DNA, unless it is found somewhere which may implicate him (like on the murder weapon). Similarly, if there is a bank robbery, a DNA profile cannot distinguish between bank clerks, customers, or robbers (again, if found somewhere relevant, then it can be more helpful—for instance, on a weapon used in the robbery). However, there is a danger with DNA matches declared early in an investigation that this information may impact on the direction of a police investigation (McCartney, 2006a). Research into miscarriages of justice show that flawed police investigations are usually characterized by early decisions made about suspects and the subsequent narrowing of the investigation. This has been called “tunnel vision,” and early decisions about the guilt of suspects have been shown to skew police investigations.

There may also be concern over the abbreviation of the criminal process. Often, the finding of a DNA match can be presented to suspects at a police station, implying that their conviction is assured, so they would do well to plead guilty and avoid a trial and perhaps a harsher sentence. Legal advice in this situation is crucial, but it is not clear whether solicitors are able to fully interrogate the relevance or significance of the DNA match at this early stage. It may be meaningless, in which case they should probably advise their clients against pleading guilty. Of course, the police must also disclose all forensic evidence in a timely fashion to ensure that the defense have a fair chance to assess the evidence and, if necessary, seek further advice or undertake further testing of the evidence.

**Presentation of DNA Evidence at Court**

DNA profiling provides probabilistic evidence and can never provide 100% proof but is presented as a match probability. As such, it has often been the source of great confusion at trial, statistics are often widely misunderstood among the public, and poor reporting by journalists can perpetuate confusion. The expression prosecutor’s fallacy was first used by Thompson and Schumann, but debate concerning the precise definition of the prosecutor’s fallacy and the argument that there is a corollary defender’s fallacy can become highly technical. A simpler way perhaps of understanding the fallacy is as follows: the statement “if I am a monkey, then I have two arms and two legs” is true, and yet “If I have two arms and two legs, I am a monkey” is clearly not. Or if you prefer—imagine being told that there was an elephant outside your house. You would conceivably presume that the elephant outside had four legs. However, if you were told that there was an animal outside your house with four legs, it would be rather odd to jump to the conclusion that the animal must be an elephant!
The trial judge directed the jury that if this evidence was to be believed, guilt expert had testified that it was his opinion that the offender was the defendant. There remains a possibility the DNA evidence, that while there was a very small group of other people who could match the DNA profile, the defendant was only one of this small group. If there is a full SGM+ match of the suspect's DNA and that recovered from a crime scene, then the rarity is expressed as "of the order of one in a billion." Even though this is very powerful evidence, it still does not, by itself, prove conclusively that the defendant was the source of the crime scene profile. There remains a possibility that somebody else (especially a close relative) may have the same profile.

The leading case in England and Wales on presenting DNA evidence at trial is known as Doheny and Adams (R v Doheny & Anor, 1996). In Doheny, a DNA expert had testified that it was his opinion that the offender was the defendant. The trial judge directed the jury that if this evidence was to be believed, guilt had been conclusively proved. This was contrary to the proper interpretation of the DNA evidence, that while there was a very small group of other people who could match the DNA profile, the defendant was only one of this small group. In Gary Adams' original trial, both the expert and prosecutor committed the prosecutor's fallacy. The Court of Appeal ruled that it was vital, in light of the increasing use of DNA evidence, that the profiling process be understood and that the manner in which the evidence is presented be made as clear as possible. In R v Dennis Adams (1996), the Court of Appeal rejected the argument that the complexity of DNA evidence was a ground upon which such evidence could be excluded. However, the Court ordered a retrial because the defense team's use of the Bayes theorem (a logical method of weighing different pieces of evidence) had "plunged the jury into inappropriate and unnecessary realms of theory and complexity deflecting them from their proper tasks."

The courts have further considered the weight of DNA evidence in the cases of R v Watters (2000) and R v Mitchell (2004). Watters was originally convicted of four burglaries based on a DNA match with samples from cigarette butts found at the scene of burglaries. The prosecution relied on the fact that the defendant was a smoker, lived locally, and was male. On appeal it was argued that the DNA evidence was weak (there was only a partial profile giving a match probability of 1 in 9,000), and the defendant had a brother—which reduced the match probability to 1 in 267. The DNA expert claimed that this DNA evidence should not have been used in isolation at trial, and the Court of Appeal concluded that the case should not have been put before a jury because of the confusion over the brothers. In R v Mitchell, the appellant successfully argued that the fact that DNA swabs taken from the victim did not match his DNA profile strongly supported his defense of mistaken identity. The trial judge had summed up the DNA evidence at trial, stating that it was entirely neutral and could not assist the jury. The Court of Appeal disagreed, finding that a "non-match" could indeed be powerful evidence, which the jury should consider. The Court concluded that when considering DNA evidence, judges should take great care not to raise scientific speculative possibilities.

There remains a risk that individuals could be charged with a serious criminal offense on the basis of a circumstantial association with the crime scene represented by a DNA match and, if lacking a cast iron defense, it may be very difficult to challenge the DNA evidence. The triers of fact will have to take account of other evidence—for example, alibi evidence (or lack of it), differences in any description of the offender, and the character of the defendant—and decide whether on all the evidence they can be sure of guilt. Special care needs to be taken when DNA is located on a "mobile" object—such as a cigarette butt—which may have originally been dropped somewhere other than where it was found. A corrupt investigator or devious criminal could attempt to deliberately contaminate a crime scene with an innocent person's DNA.

The Impact of DNA at Trial

In the United States, research has shown that prosecution reliance upon DNA evidence resulted in longer sentences (Purcell, Thomas-Winfree, and Mays, 1994). The hypothesis is that judges were "punishing" defendants for wasting time, when the DNA evidence made their conviction almost certain. In Australia, it has been found that juries are 33 times more likely to convict a defendant when the prosecutor produces DNA evidence (Brilsky, 2004), and that most juries had been exposed to DNA through popular culture before trial and anticipated its significance—they went into the courtroom convinced that DNA would be compelling evidence and were happier to convict—even if the DNA evidence was not that significant or helpful in the case (Findlay and Grix, 2003). Such high expectations of DNA makes essential the proper education of legal professionals and jurors.

There has been no equivalent research in England and Wales, but what is clear is that expert opinions can be highly persuasive during both investigations and trials. There have been reported examples of misunderstanding of DNA (and scientific evidence more generally) by judges, lawyers, police, journalists, and even forensic scientists. DNA results may be misleading during both investigative and trial and anticipated its significance—they went into the courtroom convinced that DNA would be compelling evidence and were happier to convic—t—even if the DNA evidence was not that significant or helpful in the case (Findlay and Grix, 2003). Such high expectations of DNA makes essential the proper education of legal professionals and jurors.
Such difficulties may well result in undeserved acquittals or, perhaps more likely, wrongful convictions.

**NATIONAL DNA DATABASES**

To maximize the utility of DNA profiling techniques, nearly all developed countries have a DNA database or databank. There is huge variety in the laws governing these databases and whose DNA may be stored on them, but their general aim is to store the DNA taken from unsolved crime scenes so that they may be matched with any future suspects, as well as store the DNA of convicted offenders so that their future crimes may be detected more easily. Many countries limit their DNA databases to serious offenders or are time-limited, whereas others can include those who have committed more minor offenses.

**The UK National DNA Database**

No single legislative instrument or Act of Parliament established the UK National DNA Database (NDNAD), or the police powers to take and retain biological samples from citizens. Instead, the collection, storage, and use of DNA and biological samples has been facilitated piecemeal by successive amendments to the Police and Criminal Evidence Act (PACE) 1984. Over the course of a few years, police sampling powers have been significantly extended by a series of amendments. The Criminal Justice Act 2003 extended sampling powers, permitting the nonconsensual taking of DNA samples upon arrest for a recordable offense. These samples are to be retained on the NDNAD and speculatively searched and used: “for purposes related to the prevention or detection of crime, the investigation of an offence or the conduct of a prosecution” (PACE s.64). However, the European Court of Human Rights has now ruled that these laws breach human rights and are now under review (S & Marper v UK, 2008).

In 1995 the UK’s National DNA Database was established, consisting of electronic records of DNA profiles obtained from individuals and crime scenes (a 20-digit code). In addition, all DNA samples are retained from individuals (the crime scene samples are kept only until the crime has been through the courts). The NDNAD has seen massive growth, so the United Kingdom has the biggest proportion of their population on the database in the world—at nearly 7% of all citizens. By late 2008, there were over 5 million DNA profiles on the database, representing over 4.5 million individuals (there are significant numbers of replicates, estimated to be 14% of the total). Of these individuals, just under 25,000 are from “volunteers” (victims, witnesses, etc.). Currently, 30,000 citizens are added to the NDNAD each month, but this number may drop in light of the European Court ruling. There are also nearly 300,000 crime scene samples stored on the NDNAD. During 2006–2007, over 40,000 matches were made between crime scene and one or more individuals. The database is not surprisingly, dominated by males (80% of the total) and young people—8% of samples were taken from individuals who were under 14 when their DNA was loaded. There are growing concerns around not only the numbers of “innocent” people on the database (an issue which now has to be addressed), but also the numbers of young people and the disproportionate number of people from ethnic minorities on the database.

The NDNAD is governed by the NDNAD Strategy Board, supported with the creation in late 2007 of an NDNAD Ethics Board. The NDNAD Custodian Unit is responsible for overseeing delivery of NDNAD operations and the Standards of Performance for forensic science laboratories. The Custodian is entrusted with maintaining and safeguarding the integrity of the NDNAD and developing policy. A mix of private organizations and police laboratories are approved to provide DNA profiles from criminal justice and/or crime scene samples to the NDNAD. The UK Accreditation Service (UKAS) accredits laboratories in line with two major standards—ISO/IEC 17025 and ISO 9000:2000—and the Custodian also has stringent quality criteria and checks. In 2007, the role of “Forensic Regulator” was also created, with the Regulator to play a significant role in the future governance of the NDNAD.

The legal parameters for use of the NDNAD are clearly delineated in the Police and Criminal Evidence Act of 1984; the prevention and detection of crime, the investigation of an offense or the conduct of a prosecution, or identifying a deceased person. This affords some certainty about how the NDNAD may be lawfully used. It precludes the use of the NDNAD in medical or other research, or in paternity disputes. Such terms, however, may be subject to a wide interpretation that expands the range of uses to which the information on the databases may legitimately be put. While, to date, forensic databases have been used primarily to match known suspects with crime scenes, they are increasingly used in efforts to identify unknown suspects: by searching the NDNAD for possible relatives of a perpetrator or for predicting the likely ethnic appearance of an unidentified suspect, for example.

**New Zealand and Australia**

In 1996, New Zealand was the second country to establish a national forensic DNA database and remains the only country in which the custodian of the database is a private entity. The passing of the Criminal Investigations (Blood Samples) Act 1995 brought together the New Zealand Police and the Institute of Environmental Science and Research to create a national DNA database, with strict rules regarding sampling of individuals. A DNA match can only
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The use of DNA testing has not been without controversy, with an inquiry into the investigation of a Christchurch man for murder when his DNA "matched" a sample taken from a murder scene, yet it was subsequently proven that the man had never been to Wellington, where the murders had occurred. A subsequent inquiry in 1999 found that there had been contamination of samples in the laboratory during processing (McCartney, 2006b).

In 1990, the Australian federal government, as well as a number of states and territories, had begun to undertake forensic DNA analysis, and in 1992, the National Institute of Forensic Science (NIFS) began developing national standards for forensic DNA laboratories throughout Australia. In 1999, the Model Forensic Procedures Bill was published, to guide states on the construction of their DNA legislation. While not addressing who such databases may include, it spelled out procedures for sampling and the destruction of samples. Many of the states closely followed the Model Bill when writing their DNA legislation, and others have subsequently amended their legislation to bring it closer into line with the bill, while retaining some variations.

This variation among jurisdictions has led directly to significant problems in creating a national database. In 2001, the federal government established the CrimTrac Agency, a law enforcement agency set up to facilitate national crime fighting initiatives including a DNA database—the National Criminal Investigation DNA Database (NCIDD). Individual states and territories have then had to draw up state-level legislation to enable their voluntary involvement in NCIDD, and the writing of bilateral agreements between each of the states. This has proved to be a slow, painstaking process which has suppressed the ability of states to cross-check DNA samples across the country.*

The United States: CODIS

In 1989, Virginia became the first state to create a DNA database which, while limited at its inception to violent and sexual offenders, has subsequently expanded and been joined by DNA databases from all other states in the United States. Every state now collects DNA from offenders, though their sampling powers vary significantly. The FBI were first authorized to establish a national DNA database with the passing of the DNA Identification Act of 1994. This legislation created CODIS, a supra-database consisting of DNA databases at the local (LDSI), state (SDIS), and national levels (NDIS), with over 170 public laboratories contributing to the database. The NDIS has two indexes: a forensic index with profiles obtained from crime scenes and an offender index with profiles of individuals, these profiles consisting of 13 STR loci. A "match" on the NDIS is reported to the submitting laboratories which then communicate on validating (or refuting) the match and adding the necessary identifiable information (which is not held on the NDIS). As of October 2008, CODIS had produced over 77,700 hits.7

Since becoming fully operational in 1998, CODIS has collated 241,685 forensic profiles and 6,384,379 offender profiles,8 making it the largest DNA database in the world (California alone has the third largest DNA databank in the world).9 However, an increase in federal funding following the 2003 "President's DNA Initiative," which saw $1 billion poured into training and assistance, and the continued expansion of database laws such as the DNA Fingerprinting Act of 2005 mean that CODIS is set to grow dramatically in the coming years.10 In 2000, the United States also commenced the creation of the National Missing Persons DNA Database (NMPPD), which can hold both conventional STR DNA profiles and also mitochondrial (mtDNA) profiles. Mitochondrial DNA is found in the mitochondria of the cell and is inherited only from the mother, making them useful for missing persons investigations but not criminal investigations where individualization is necessary.11

Europe

The European Council has passed resolutions encouraging member states to develop national DNA databases and permit the exchange of profiles (see Johnson and Williams, 2007). The European Network of Forensic Science Institutes (ENFSI) DNA Working Group report that across the European Union there have been almost universal moves to expand DNA databases, with Ireland remaining one of the last to establish a permanent database of DNA profiles, with legislation intended to be passed in 2009 (Report on ENFSI, 2009). However, despite the universal enthusiasm, there are huge variations across Europe with respect to police powers to collect and retain DNA (Williams and Johnson, 2005). At least 20 member states permit the compulsory taking of DNA samples and retaining DNA profiles on databases. However, in many of these states, the power to take samples is limited to certain circumstances, most often being limited to being taken in connection with serious offenses. Further, in most of Europe, DNA is destroyed upon acquittal, although some (e.g., Scotland, Austria) can retain DNA if the suspect continues to be a "risk" for future serious offending. While variations in law governing sampling and retention are many, it may be that in the future, laws will come to more closely align when pressures for data sharing and harmonization grow. The European Court of Human Rights has also recently given a clear steer on when the retention of DNA may be justified, which will lead to modification of the UK's laws to bring them more into line with their European neighbors.
CHAPTER 14 Understanding the Role of Forensic DNA: A Primer for Criminologists

The Future?
The Secretary General of Interpol recently stated that DNA profiling "has benefited mostly the wealthiest of countries" (Noble, 2007), yet policy in this area is developing rapidly and is highly ambitious. There are moves for DNA databases around the world to be compatible and enable searching for DNA matches across borders. The scientific techniques are also continually being refined and improved upon, with mobile DNA testing and automation also a clear aim. However, the use of DNA technology and the relevant enabling legal reforms that have permitted police sampling and databasing have belatedly begun to attract critical attention from different quarters. For example, forensic scientists have conducted research on the scientific principles underpinning DNA profiling, to advance the scientific capabilities of the technique. There has been some examination of forensic identification technologies from a sociological perspective (e.g., McCartney, 2006b) and by sociologists (e.g., Williams and Johnson, 2008), examining impacts upon legal systems and social relations. More recently, ethical inquiries have been made by bioethicists (Nuffield Council on Bioethics, 2007), while politicians have inquired into the status of forensic science in the United Kingdom generally (House of Commons, 2005) and, more specifically, the operation and governance of surveillance technologies including the NDNAD (Home Affairs Committee, 2008). There are also serious reasons to suggest that the presumed "infallibility" of DNA requires challenging, in light of continued controversies surrounding DNA.

INTERNATIONAL EXCHANGE
The use of DNA in support of criminal investigations and counterterrorism measures is an important feature of contemporary efforts across the world to ensure security. The use of DNA is also growing among intelligence and other EU-wide security agencies, while rapidly evolving efforts to tackle transnational crime entail the exchange of DNA across jurisdictions and state borders (e.g., Lewis, 2007). Indeed, the international utilization and exchange of forensic DNA is becoming an expectation, with the Schengen Information System (SIS) in Europe, and more recently the Prum Treaty, which stipulate that there should be shared access to law enforcement information across agencies in Europe. Yet there are formidable scientific challenges with harmonization. In Europe, DNA databases in member states are not compatible and cannot be searched against each other meaningfully. Interpol has also attempted to facilitate international transfer of DNA data using the Interpol Standard Set of Loci (ISSOL), and there is an Interpol DNA Charter to monitor transfers, with oversight provided by the DNA Monitoring Group. In 2005, Interpol's DNA database became operational, while more recently, Interpol launched the DNA Gateway, which enables the comparison of DNA profiles to take place online. However, there is a risk that while scientists may attempt to answer the demands of interoperability, scientific developments move faster than legal, ethical, or political regimes can respond. The sending of such "personal" information beyond jurisdictional boundaries is controversial, not least because of a lack of formal procedures and legal guarantees that there will be no scope for unauthorized storage, further manipulation, or exchanges of the data. There are no bodies charged with oversight powers to monitor the international exchange of forensic DNA and no one to whom individuals may direct inquiries or complaints. Such omissions are significant, with continued growth in agreements to exchange forensic DNA data internationally and in proposals for global databases. There have yet to be legal rulings on whether DNA evidence from another country is admissible in domestic courts, which is vital if convictions are to be secured.

ETHICAL ISSUES
The forensic use of citizens' DNA demands the highest operating standards in terms of accountability, security, quality assurance, and ethical standards. Medical databases are strictly governed and subject to laws governing human rights and data protection. However, many DNA databases held by state agencies are not so clearly governed, yet robust ethical governance is vital to ensure "the liberty, autonomy and privacy of those whose details are recorded on such databases, and also to help engender public trust and confidence in their existence and use as part of a criminal justice system" (Nuffield Council on Bioethics, 2007, p. 51). There are imperatives that forensic databases are effective and efficient and their utility maximized at the same time as minimizing risks of abuse or other potential harmful effects. The UK Nuffield Council of Bioethics have found significant room for improvement in the use of DNA and fingerprints, while the National Ethics Councils of France and Portugal have highlighted concerns and established principles for the ethical collating and retaining of biographical information of citizens (French Comité, 2007).

The use of DNA remains sensitive, and the ethical issues involve the police "justifying" that the powers they have are proportionate in the fight against crime. The Nuffield Council 2007 report concluded that there must be a balance between personal liberty and the common good. Many now believe that the popular "no reason to fear if you are innocent" argument commonly used is not a sufficient justification for the full extent of police powers. The European Court of Human Rights in late 2008 agreed (S & Harper v UK, 2008), stating that ..."The blanket and indiscriminate nature of the powers of retention of the fingerprints, cellular samples and DNA profiles of persons suspected but not convicted of offences ... fails to strike a fair balance..."
between the competing public and private interests and..., constitutes a disproportionate interference with the applicants' right to respect for private life and cannot be regarded as necessary in a democratic society.

The Court also considered that the retention of personal data of juveniles may be especially harmful.

Oversight and management of DNA databases are becoming increasingly important as more ways of using them are found. While most uses can be classified "operational," in that the use is directly related to particular police investigations, there are emerging "research" uses. Research could be conducted using the electronic records (profiles) on the database or the archived biological samples from which the DNA profiles have been generated. Expanding use of the databases beyond "operational" uses makes crucial the need for robust ethical oversight and regulation, particularly in instances in which the research uses the archived biological samples. Advanced levels of ethical and scientific review are necessary because these samples are not initially obtained with consent, unlike those collected in medical settings, and remain easily traceable to named individuals.

**STRETCHING THE SCIENCE**

In many countries, the focus of debate has been on how to populate DNA databases. However, it is being more widely recognized that the crucial element for DNA databases to be effective in crime detection is the collection of DNA samples from crime scenes, without which the DNA of individuals, whether serious criminals or not, is rendered meaningless. A lot of work has been undertaken on automation, with most modern laboratories now equipped with robots and computerized testing processes. There have also been efforts to create mobile DNA testing capabilities to enable rapid testing at a crime scene. This has gone so far as attempts to create a "lab-on-a-chip" technology, with visions in the future of police officers able to test DNA on the spot (much as they can now do with fingerprints). So far, trials of mobile DNA analysis laboratories (a Forensic Response Vehicle or FRV) have demonstrated the feasibility of obtaining profiles at a crime scene, which could speed up investigations. Their significant operating costs have not been justified for standard use to date.

However, there have been significant developments in laboratory methods. The DNA testing now undertaken is far less ambiguous than the original "DNA fingerprint," which left significant room for debate, although DNA profiles still require expert interpretation. This need becomes critical when dealing with mixed samples or partial profiles. Techniques to separate mixed samples and to analyze degraded samples (Mitochondrial DNA Analysis and Y Chromosome Analysis are used in such instances) are becoming more widespread and commonly used.13

**Partial Profiles**

DNA samples may, for a variety of reasons, be degraded or contaminated, requiring a more detailed examination of any resulting profile. Match probabilities will be less decisive than for a full profile and should attract caution. In R v Bate (2006) there was a thorough examination of issues arising in cases in which only a partial DNA profile was found at the crime scene, concluding: "We can see no reason why partial profile DNA evidence should not be admissible provided that the jury are made aware of its inherent limitations and are given a sufficient explanation to enable them to evaluate it...."

**Mixed Samples**

DNA samples originating from more than one person always require interpretation, and a court has to demand evidence of a valid analysis, with interpretation of mixtures heavily dependent on the expert opinion of the reporting officer. Profiles provided by known innocent bystanders can often be subtracted from the mixed profile to identify peaks of unknown origin, and in rape cases, special techniques may identify a male-specific profile from a vaginal swab. Computer programs for identifying individual profiles in mixed samples may be ineffective with very small samples.

**Low Template Number DNA**

While DNA technology has advanced to be able to analyze ever smaller samples, very small samples give rise to concerns over the presentation of DNA evidence. Concerns about the LTN DNA technique focus on the heightened possibility of contamination when very small amounts of material are amplified to obtain a profile. Contamination, whether deliberate or accidental, is a major issue which is heightened when dealing with very small samples. Samples can easily be contaminated with DNA from one of the police or laboratory team if strict preventive measures are not taken. Elimination databases are maintained, which hold the profiles of potential "innocent donors" of DNA, and hence enable their DNA profiles to be excluded from the investigation.14 However, many individuals are involved in the transfer of DNA from a crime scene through the process of collection, storage, transport, and laboratory analysis. In the trial of Sean Hoey for a series of bombings in Northern Ireland, the prosecution relied on LTN DNA evidence (R v Hoey, 2007). The defense, however, were able to demonstrate that the collection and storage of exhibits had not been undertaken with due diligence. At the time of the investigation, neither the army nor police were cognizant of the concerns that...
would later arise with regard to DNA collection. This was then compounded by haphazard storage and transportation of exhibits between the police and Forensic Service of Northern Ireland.

**Familial Searching**

Often, a speculative search on a DNA database may come up with close matches—often from a blood relative. This ability to find partial matches on the database can be used to find the blood relatives of perpetrators, which can provide the police with possible new investigative leads. So-called familial searching has now been used around the world to support serious crime investigations. This ability raises a lot of ethical issues and at times may be of limited use because the search may produce a list of numerous possible relatives. However, in the United Kingdom, there are several cases in which use of the technique has led to the conviction of serious criminals.

**A DNA Photofit?**

The ultimate in crime-fighting intelligence tools would be for suspect DNA found at a crime scene to be sent to the laboratory and for the scientists to then return a "photofit" of the suspect. The similarity of identical twins clearly demonstrates that physical likeness is influenced by genes, and in principle, physical characteristics might be predictable. At present, this possibility remains incredibly complex, although certain combinations of alleles can give an indication of ethnic origin (inferring ethnicity), a technique that has been used in a number of police investigations into serious crimes when they have stalled in an effort to get as much information as possible on the crime scene stain donor. There have been some developments in identifying redheads (though it cannot tell whether someone is bald or has dyed his or her hair). Several genes have also been identified that contribute to determining eye color, and it is known that skin color is determined by a series of different genes, some of which have been specifically identified. Perhaps even better still than a photofit would be the suspect’s name. Since a man’s Y chromosome and, most often, his surname are both inherited down the male line, there is some correlation between Y-chromosome markers and surnames. For unusual surnames, the correlation has been sufficient to help narrow a pool of suspects. Such inferences would, of course, be complicated by cases in which individuals had been adopted or otherwise did not share the surname of their biological father.

**THE “GOLD STANDARD” OR FOOL’S GOLD?**

With the significant investments made around the world in developing forensic DNA capabilities and the continued representations of DNA as the “gold standard” of identification, it is not surprising that many believe DNA to be infallible. However, there are many reasons to believe that there may have been an amount of hype surrounding DNA, and our complete confidence in it may have been misplaced. Where the science cannot be said to have been stretched (as perhaps in the case of Low Template DNA, which remains controversial in forensic assays), there still remain instances in which DNA has failed, normally due to human error or corruption; lack of quality control or regulatory oversight; or simply the misuse or misrepresentation of DNA and its problematic place in an adversarial legal system. In England and Wales, there have been lapses in police processes, one of which saw a serial rapist and murderer evading conviction when the DNA sample that should have been taken would have linked him with a series of offenses, preventing him from killing again. In 2005, it was revealed that there had been nearly 26,000 DNA profiles identified as having errors and were therefore not loaded onto the NDNA between 1995 and 2004. As a result of the failure to load these profiles, it was determined that 183 crimes had gone undetected (Lords Hansard, 2007).

In addition to problems detailed earlier of DNA matches not being converted into detections, failing to load DNA profiles onto databases has been a perennial issue for laboratories in the United States, with huge backlogs, meaning many laboratories taking months, if not years, to process DNA evidence. In Virginia, investigations in 2006 found that a quarter of the state’s sex felons were not on the DNA databank and a further audit undertaken in 2007 found that 20% of felons in that state did not have their DNA loaded onto their DNA databank (Fisher, 2008). Backlogs in state laboratories have become such an issue that federal funding is available to laboratories to "handle, screen, and analyze backlog forensic DNA casework samples, as well as to improve DNA laboratory infrastructure and analysis capacity, so that forensic DNA samples can be processed efficiently and cost effectively." Such backlogs, however, do not appear yet to be an historic issue; indeed, many laboratories have now deduced that having a backlog attracts large federal grants, making it in their interest to build up and maintain a backlog to secure extra funds.

In addition to such failures to utilize the DNA evidence available, there have been human errors that have seen individuals wrongly implicated in crimes. In most instances, individual forensic scientists who were dishonest or whose work was incompetent have been discovered, although many not until years had passed, requiring rectifying of their casework. However, there have been whole laboratories in the United States whose DNA work has come under critical scrutiny, with laboratories in Virginia, Washington, and North Carolina, among others, being opened to external investigators. The deficiencies in the work at the Houston State Laboratory were such that the serology part of the lab was closed down and a major independent review undertaken (Bromwich, 2007). In most instances, mistakes arise from cross-contamination and mislabelling of samples. The FBI DNA Advisory Board in 1998 required laboratories
to maintain contamination logs and corrective action files. These are required to be updated when contamination is discovered, and they have to "follow procedures for corrective action whenever proficiency testing discrepancies and/or casework errors are detected." When defense attorneys request these documents from the laboratory, it is often surprising just how many episodes of contamination are recorded, raising awkward questions about how frequently contamination/mistakes take place in laboratories and may not be picked up.

Despite the incidence of corruption, errors, police mishandling or omission, legal misinterpretation or misrepresentation, DNA continues to be portrayed as the "gold standard" (NAS, 2009, pp. 5-3):

DNA typing is now universally recognized as the standard against which many other forensic individualization techniques are judged.

DNA enjoys this pre-eminent position because of its reliability and the fact that, absent fraud or an error in labelling or handling, the probabilities of a false positive are quantifiable and often miniscule....

While this may be a valid representation in perfect laboratory conditions, it may be that caution is still required when dealing with forensic DNA analysis. While nearly all other forensic sciences are now under increasing critical scrutiny and often being compared unfavorably to DNA, it may be dangerous to become complacent about DNA and allow no room for doubt when dealing with this powerful evidence.

CONCLUSION

The advent of forensic DNA profiling has revolutionized the detection of offenders across the world. Thousands of offenders have been caught—many several years after they believed they had escaped detection—while thousands more have been eliminated as suspects in police investigations. Men and women continue to have their wrongful convictions overturned and their innocence proven with DNA tests. The advantages of DNA then are manifold (Lake, 2006–2007, p. 4):

The benefits... are not only in detecting the guilty, but also in eliminating the innocent from inquiry, focusing the direction of the investigations, which increases police efficiency, and in building public confidence that elusive offenders may be detected and brought to justice as quickly as possible.

The power of DNA has persuaded governments internationally to create national DNA databases. In many cases, being prepared to share this information across jurisdictions and international borders in the fight against crime and terrorism.

Yet the use of DNA has perhaps not yet reached its zenith. There remain difficulties in converting DNA matches to actual convictions. The latest figures in the United Kingdom state that over half of DNA matches made between crime scenes and individuals do not result in a crime being solved.15 Indeed, the use of DNA during the criminal process has been called "a fresh filling between two slices of stale bread" (Leary and Pease, 2002, p. 8). The reason is that the "policing" and "prosecution" slices of bread are still flawed; if they are ineffective and inefficient, then the quality of the whole "sandwich" experience remains poor. A DNA detection still does not mean that an offender will be always be caught or punished for his or her offense.

To improve the effectiveness of DNA databases, improved collection of DNA at crime scenes will prove most fruitful, and limited research has been undertaken in this area. However far the laboratory processes and science may develop, the use of DNA is still restricted to indicating the possible presence of a person at a crime scene or involvement with an offense. How that person's DNA came to be found and what this means in terms of legal liability require much more than a DNA "match." It therefore remains the case that investigators, advocates, judges, and triers of fact cannot rely on DNA alone. If advanced analysis has been undertaken—such as LTN DNA—then it becomes even more vital that the possibility of contamination, misinterpretation, and innocent transfer be given due weight. While celebrating and encouraging the effective use of DNA in policing, to ignore its limitations could lead to further and greater injustice in the future.

SUMMARY

There have been several legal reforms which have enabled the use of DNA in criminal investigations and prosecutions. The advent of DNA technology in 1984 and the introduction of it into the forensic arena shortly thereafter was revolutionary, leading to changes in policing, prosecutorial policy and procedures, and so on. Once the technology was further refined and improved, DNA profiles were able to be much more discriminatory, thus leading to even greater benefits to the criminal justice system.

Changes to policing which were the result of the advent of DNA technology are many and varied. The most notable change was that DNA evidence was impartial and scientific, varying markedly from traditional investigation methods. It has now become routine to take DNA from individuals and for investigators to ask and determine whether DNA evidence may play a role in solving any given case. Specifically, DNA evidence may be used to play a role in aiding investigations, to provide intelligence to police, for the purpose of gaining cold hits, for case linkage, or as a deterrent to other possible criminals.


16To 2005–2007 there were 41,717 matches, which led to 19,949 "detections." Specifically in homicide cases, there were 452 matches declared, leading to just 88 detections.
Although DNA evidence is very convincing, it needs to be reiterated that such evidence is still probabilistic and does not speak toward guilt or innocence. Supporting evidence needs to be gathered for any case involving a DNA match. Moreover, all matches need to be interpreted in the context of the case and presented to the court as such. This is due to the fact that despite DNA being probabilistic evidence, juries are more likely to convict when it is present, and longer sentences may be imposed in these cases due to the high expectations surrounding DNA evidence.

National DNA databases have the aim of storing DNA evidence from convicted offenders so that future crimes can be detected, as well as storing DNA from unresolved cases so they may be matched to future suspects. Many countries around the world utilize these databases, including the United Kingdom, the United States, New Zealand, and Australia as well, as many countries in Europe. In the future, it is hoped that these databases may be compatible with each other and linked to enable international searching. It is anticipated that this would be of great benefit to criminal investigations as well as the war on terror.

The future of DNA technology also involves several ethical issues including security and privacy, as well as mobile testing and automation. Partial photofits must also be addressed as ethical problems. Finally, it needs to be addressed that despite its revolutionary effect on the forensic arena and reputation for being infallible, there are cases involving human error and backlogs where DNA evidence has failed.

Review Questions
1. What are the three types of DNA samples obtained by police? How are they used?
2. T/F DNA evidence can and does literally demonstrate guilt or innocence in any given case.
3. T/F Some research has shown that juries are more likely to convict if DNA evidence is present regardless of its probative value.
4. What are some problems stopping DNA databases from becoming internationally available?
5. Why would automation in DNA testing be beneficial to the forensic community?
6. Name and describe four examples of the science behind DNA evidence being stretched.
7. Describe what a DNA photofit is and how this may benefit those working in a forensic arena.
8. Name and describe the two elements which may lead DNA evidence to fail in any given case.

REFERENCES
Further Reading


R v Waters, 2009. EWCA Crim 89.


FURTHER READING


