DNA Evidence as the Basis for Conviction

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Abstract

The sufficiency of DNA evidence alone, with regard to convicting accused persons, has been interrogated and challenged in criminal cases. The availability of offender databases and the increasing sophistication of crime scene recovery of evidence have resulted in a new type of prosecution in which the State's case focuses on match statistics to explain the significance of a match between the accused's DNA profile and the crime-scene evidence. A number of such cases have raised critical jurisprudential questions about the proper role of probabilistic evidence, and the misapprehension of match statistics by courts. This article, with reference to selected cases from specific jurisdictions, investigates the issue of DNA evidence as the exclusive basis for conviction and important factors such as primary, secondary and tertiary transfer, contamination, cold hits and match probability which can influence the reliability of basing a conviction on DNA evidence alone, are discussed.

Keywords

Primary, secondary and tertiary transfer; contamination; cold hit; source; sub-source; activity and offence levels; single; mixed and partial DNA profiles; match probability; sufficiency of evidence.

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1 Introduction

Deoxyribonucleic acid (DNA) evidence is valuable in criminal cases as it assists in the investigation and prosecution of crime.[1]

Deoxyribonucleic acid (DNA) is

> [8] … the genetic material that is passed from parent to child. There are two sets of DNA molecules in a human cell. One set is found in the nucleus of the cell (nuclear DNA) and the other in the mitochondria thereof. In what follows I refer to nuclear DNA.3 The DNA molecules found in the nucleus of a human cell are the same in all cells of the human body. The DNA does not change during a person's lifetime. Except for identical twins each person's DNA is unique.
>
> [9] DNA is a double-stranded molecule composed of 46 sections termed chromosomes. A chromosome is a thread-like structure that carries genetic information arranged in a linear sequence. The chromosomes are arranged in 23 pairs. One chromosome per pair is inherited from each parent. The 23rd pair of chromosomes determines an individual's gender and differs from the others. An individual always receives an X-chromosome from the mother and either an X-chromosome or Y-chromosome from the father. Individuals with XX in the 23rdpair of chromosomes are female and those with XY are male. In what follows I concentrate on the other 22 pairs of chromosomes, called chromosomes 1 to 22.
>
> [10] Each of these chromosomes consists of linked base pairs to form a ladder-like structure. The ladder is twisted into the so-called 'double helix'. The only difference between people is that every person has a different sequence of the base pairs in the chromosomes. Every person could therefore be identified solely by the sequence of his or her base pairs. But because there are a staggering number of approximately three billion base pairs in the DNA in each human cell nucleus, this is not practically possible.
>
> [11] Scientists have however developed methods in which a small number of sequences of DNA are analysed at specific physical locations on a chromosome that are known to vary amongst individuals. Such a physical location on a chromosome is referred to as a locus (plural loci). These physical loci are referred to by codes. The codes of most loci refer to their physical locations, for instance segment 1358 of chromosome 3 is referred to as D3S1358 and segment 1179 of chromosome 8 is referred to as D8S1179, but there are also codes consisting of abbreviations of scientific terms.

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1 Meintjes-van der Walt *DNA in the Courtroom* 1.

> [12] A gene is found at a particular locus on a particular chromosome. An allele is each of two forms of a gene at a particular locus. At each locus examined a person therefore has a pair of alleles, one maternal and one paternal. This pair of alleles is called a genotype. A pair of alleles may be identical if the same allele was inherited from both parents. A set of genotypes at two or more loci form a DNA profile.
>
> [13] In this case short tandem repeat (STR) profiling was used. This form of DNA profiling is one of the most widely used. It makes use of the polymerase chain reaction (PCR) technique. This technique simulates the process which takes place when DNA is copied prior to the division of cells in the body and produces multiple exact copies of the DNA at the specific locus to be analysed.
>
> [14] An STR is a short sequence of base pairs which is repeated numerous times in tandem. The number of repetitions varies among individuals. The number of repetitions is used to name an allele, therefore five repeats of a sequence is called allele 5. As a person has two alleles at each locus, an STR profile will for instance indicate that the alleles at a specific locus are 15:15, if that allele was inherited from both parents or 15:16, if these alleles were inherited from the respective parents. The system used by the SA Police Service determines alleles at 9 loci as well as gender, as explained above.
>
> [15] The DNA fragments produced by PCR is subjected to a process called electrophoresis. This process produces a computer generated graph called an electropherogram. On an electropherogram the alleles at each locus are indicated as peaks on a baseline. If the individual received the same allele from each parent, the electropherogram of his DNA will indicate one peak at a specific locus, otherwise there will be two peaks. More than two peaks at a specific locus indicate that the sample is a mixture of DNA. The electropherogram assigns allele names to peaks. An STR profile is therefore a series of numbers that represent all the genotypes detected for each locus in a particular sample.
>
> [16] The height of a peak on an electropherogram corresponds with the quantity of DNA present. An electropherogram may however also indicate material not naturally present in DNA. This is called an artefact.[2]

The fact that very sensitive multiplexes such as Identifiler Plus[3] and Identifiler Direct,[4] are increasingly being utilised, have resulted in more

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2 *Bokolo v S* 2013 ZASCA 115 (18 September 2013) (hereafter the *Bokolo* case) paras [8]-[16].

3 "The AmpFlSTR Identifiler Plus PCR Amplification Kit has been developed specifically to address the needs of forensic casework laboratories. It utilizes the same primers as the widely used AmpFlSTR Identifiler PCR Amplification Kit and harnesses next-generation PCR amplification technology to help provide a new level of performance, data quality, and efficiency. This enables forensic analysts to recover more interpretable results from challenging casework samples with increased confidence." ThermoFisher Scientific date unknown https://www.thermofisher.com/za/en/home/industrial/forensics/human-identification/forensic-dna-analysis/pcr-amplification-forensic-dna-profiling/identifiler-plus-product-overview.html.

4 "The AmpFlSTR Identifiler Direct PCR Amplification Kit has been developed to automate the front end of the single-source sample workflow, streamlining the entire process, while maximizing sampling integrity and reliability. By eliminating the tedious steps involved in DNA extraction and purification, the Identifiler Direct kit

complex mixed results produced by questioned samples. DNA evidence contained in biological material such as blood, semen, saliva, urine, faeces, hair, teeth, bone, tissue and cells can be used as identification evidence to establish a match between the victim or those samples that were found on the crime scene on the one hand and the suspect on the other hand. This match is usually expressed as a random match probability (RMP), which is a kind of measure in population genetics to measure the probability of an unrelated person, randomly picked out of the general population, matching the genotype derived from the evidence.[5] A genotype has a number of alleles, and each allele has a frequency in a certain population. It is often expressed as "the chance is 1 in 350 billion people"[6] that some (particular) person other than the suspect would leave a stain similar to the actual stain.[7]

DNA evidence may be used to address four different levels at issue in a criminal case, namely source, sub-source, activity and offence.[8] DNA evidence, for example, can be used to address the following questions in a rape case:

a) Source level: Is the accused the source of the semen found at the crime scene?

b) Sub-source level: Is the DNA found at the scene or in the victim's vagina DNA from semen of the accused or other cellular material?[9]

c) Activity level: Did the accused have intercourse with the victim?[10]

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facilitates high-throughput processing with a simple, easy-to-automate protocol that requires a less sophisticated and less expensive robotic platform." ThermoFisher Scientific date unknown https://www.thermofisher.com/za/en/home/industrial/forensics/human-identification/forensic-dna-analysis/pcr-amplification-forensic-dna-profiling/identifiler-plus-product-overview.html.

5 Ligertwood 2011 *Syd LR* 487.

6 See *S v Nyembe* 2014 1 SACR 105 (GSJ) (hereafter the *Nyembe* case) para 7.

7 Brenner date unknown http://charlesbrenner.com/profile.htm. The expert, should however, be careful that he does not commit the prosecutor's fallacy, which would be expressed as "The chance is one in 350 million people that someone (anyone) other than the suspect left the stain".

8 Graham *Presentation and Examination of DNA Evidence* 112; Cook *et al* 1998 *Sci Justice* 231-239.

9 The distinction between this level and source level is important if the accused claims that his DNA is present as a result of simply touching the victim.

10 In this case the defence of consensual sex will still be available to the accused. See Semikhodskii *Dealing with DNA Evidence*. This issue involves both legal theory and practice. One should ask oneself whether DNA evidence on its own is sufficient to prove the elements of *actus reus* and *mens rea* on the crime in question. Absence of either element will not dispose the burden that the accused has committed the offence. For instance, semen matching the DNA profile of the accused found in the

d) Offence: Did the accused rape the victim?[11]

Whether DNA evidence alone is sufficient to convict will be influenced by the following:

a) DNA as circumstantial evidence;

b) whether the sample was properly collected at the crime scene, and from the victim or suspect;

c) whether the chain of custody is intact;

d) whether the sample was not contaminated in the laboratory;

e) whether the sample, after being received at the forensic laboratory, was properly analysed in line with the appropriate scientific protocols; and

f) whether the reading and interpretation were accurate. This, in turn, can be influenced by whether one is dealing with the following phenomena which are referred to in the discussion below:

    i) single DNA profiles;

    ii) mixed DNA profiles;

    iii) partial DNA profiles;

    iv) or cold hits.

The discussion in this article follows the above sequence.

2 DNA as circumstantial evidence

DNA evidence is not direct evidence that a crime has been committed or by whom. DNA evidence is ultimately considered to be circumstantial

victim's vagina does not automatically indicate that the victim has been raped. Lack of consent on the sexual intercourse, which has taken place must be proved by adducing other evidence or testimony. Semikhodskii *Dealing with DNA Evidence* 137.

11 Aitken, Roberts and Jackson 2010 https://pdfs.semanticscholar.org/004e/55d7a450c0a47f7976e762c06142b5dc03b8.pdf paras 3.4-3.8.

evidence.[12] It does not definitively prove the point which needs to be proved and only provides a strong inference in favour of that point.

In dealing with circumstantial evidence, the two cardinal rules of logic as set out in *R v Blom*[13] (hereafter the *Blom* case) should be borne in mind:[14]

> (1) The inference sought to be drawn must be consistent with all the proved facts. If it is not, the inference cannot be drawn.
>
> (2) The proved facts should be such that they exclude every reasonable inference from them save the one sought to be drawn. If they do not exclude other reasonable inferences, then there must be a doubt whether the inference sought to be drawn is correct.

The defence challenge to the evidence should therefore not be in a piece-meal fashion. The court in *S v Reddy*[15] warned against this, where it stated as follows:[16]

> In assessing circumstantial evidence, one needs to be careful not to approach such evidence upon a piece-meal basis and to subject each individual piece of evidence to a consideration whether it excludes the reasonable possibility that the explanation given by an accused is true. The evidence needs to be considered in its totality.

The court in *R v Difford*[17] stated that:[18]

> ... no onus rests on the accused to convince the Court of the truth of any explanation he gives. If he gives an explanation, even if that explanation be improbable, the Court is not entitled to convict unless it is satisfied, not only that the explanation is improbable, but that beyond any reasonable doubt it is false. If there is any reasonable possibility of his explanation being true, then he is entitled to his acquittal ...

In the *Nyembe* case, DNA was the only evidence implicating the accused.[19] The court considered all the facts in the matter and ruled that the DNA result obtained was corroborated by the similar fact evidence of three incidents in which similar offences were committed, within three months, in the same area and at the same time, by one man, who was inferred to be the accused.[20] Taking into account the evidence as a whole, the accused was

12 The *Bokolo* case para 18.
13 *R v Blom* 1939 AD 188 (hereafter the *Blom* case).
14 The *Blom* case 202-203.
15 *S v Reddy* 1996 2 SACR 1 (A) (hereafter the *Reddy* case).
16 The *Reddy* case 8C-D.
17 *R v Difford* 1937 AD 370 (hereafter the *Difford* case).
18 The *Difford* case 373.
19 The *Nyembe* case para 4.
20 The *Nyembe* case para 9.

found guilty beyond reasonable doubt and convicted of the crimes committed.[21]

In *Seboko v S*[22] the appellant was convicted of two counts of rape and the court held that the DNA evidence adduced, corroborated by other circumstantial evidence,[23] proved the rape charge against the appellant beyond a reasonable doubt.

In the *Bokolo* case, the appellant was charged with murder, rape and indecent assault of his daughter. The appellant was tried in the High Court and was only convicted on the charge of rape. The appellant appealed to the Supreme Court of Appeal. He contended that he was not involved in the rape and alleged that he had not been at home at the relevant time.[24] The appellant maintained that, on the day of the offence, he went to work, then visited the shebeen[25] across from his home at 15h00 hours and only retired to his home to sleep at 22h00 hours.[26] The prosecution's case against the appellant rested entirely on the results of DNA testing. DNA samples from the victim's private parts were secured, using two sanitary pads, namely pad 1 and pad 2.[27] Both pads contained DNA mixtures of at least three males.[28]

With regard to the *Bokolo* case, the Supreme Court of Appeal stated that:[29]

> Evidence that the STR profile of an accused person matches that of a sample taken at the scene or can be included therein, is circumstantial evidence. The weight thereof depends on a number of factors.
>
> These include:
>
> i) the establishment of the chain evidence, i.e. that the respective samples were properly taken and safeguarded until they were tested in the laboratory;
>
> ii) the proper functioning of the machines and equipment used to produce the electropherograms;
>
> iii) the acceptability of the interpretation of the electropherograms;

21 The *Nyembe* case para 9.
22 *Seboko v S* 2009 JOL 23588 (NCK) (hereafter the *Seboko* case),
23 The circumstantial evidence included the complainant's oral reports regarding the alleged rape to, *inter alia*, a policewoman and other lay witnesses and the pointing out of the scene by the complainant. See the *Seboko* case para 4.
24 The *Bokolo* case para 3.
25 A tavern or an informal venue where alcohol is sold.
26 The *Bokolo* case para 3.
27 The *Bokolo* case para 24.
28 The *Bokolo* case para 24.
29 The *Bokolo* case para 18.

iv) the probability of such a match or inclusion in particular circumstances;

v) the other evidence in the case.

Van der Merwe AJA further stated:[30]

> If the STR profile of an accused person in fact differs from the profile retrieved from the sample taken at the scene, even in respect of only one allele, the accused person must be excluded as a source of the crime scene DNA. However, the converse is not true. Because only a limited number of STR loci are analysed, an STR profile cannot identify a person. Therefore, the weight to be attached to evidence of an STR profile match or inclusion in the first place depends on the probability of such a match or inclusion occurring in a particular population. Without such evidence the STR profile match or inclusion means no more than that the accused person cannot be excluded as a source of the crime scene DNA.

Therefore, conviction based on DNA evidence, and especially where the sample contains a mixture of DNA profiles, will require other evidence to be established. In the case of *Bokolo*, a mixture of DNA profiles from at least three men was present in the fluids found on the victim.[31] In cases where there is a mixture of profiles, it is difficult to ascertain the exact match of the perpetrator's profile, linking him or her to the crime. As the court explained, if the profile is found in several individuals, a match between the profile of the accused person and the crime scene DNA will have little or no probative value.[32]

3 The proper collection of the sample from the crime scene, the victim and / or the suspect

DNA sampling has developed to such an extent that one cell is enough to produce a profile.[33] Issues such as the type of material (blood, semen, skin cells), how the DNA may have been transferred and how long the DNA has been present at the crime scene or on the exhibit, must be considered.[34]

Persons who are qualified to collect and test samples should take every possible precaution to avoid contamination of samples or transfer of DNA.[35]

30 The *Bokolo* case para 20.
31 Bokolo's DNA together with DNA samples of other men, was found on his daughter's private parts. See the *Bokolo* case para 24.
32 The *Bokolo* case para 21.
33 Findlay *et a*l 1997 *Nature* 555-556.
34 Taupin *Introduction to Forensic DNA Evidence* 25.
35 Meintjes-van der Walt 2010 *SAJCJ* 373-374.

The quantity of the DNA tested is important – if there is too little or too much DNA present in the sample, the test is likely to fail.[36] Too much sample may skew the sample and too little may not produce sufficient results.[37] Therefore, the amount of DNA extracted must be measured to ensure that it meets the appropriate range.

The reliability of low template analysis of DNA profiles was affirmed by the English Court of Appeal in *R v Reed and Reed; R v Garmson*[38] (hereafter the *Reed* case), where the Court stated:[39]

> [A] challenge to the validity of the method of analysing Low Template DNA by the LCN process should no longer be permitted at trials where the quantity of DNA analysed is above the stochastic threshold of 100-200 picograms in the absence of new scientific evidence ...

According to the Court's interpretation, the stochastic threshold refers to the minimum amount of DNA needed to produce a reliable profile using the low template DNA method.[40]

The amount of DNA normally used in Lower Copy Number (LCN) profiling in South Africa is between 100 picograms and one nanogram or 1000 picograms.[41]

4 The chain of custody and the issue of contamination

The chain of evidence relating to the collection, sealing, safekeeping, sending and receipt by the forensic laboratory for analysis, rules out any tampering or substantial alterations of the evidence. Meintjes-van der Walt regards chain evidence as to the chain in custody, regarding "the means of verifying the authenticity and legal integrity of trace or sample evidence by establishing where the evidence has been and who handled it prior to the trial".[42] She argues that the chain of custody lays a proper foundation of connecting the evidence to the accused and as such the critical links in the chain of custody should be followed.[43]

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36 Puch-Solis *et a*l 2012 http://eprints.nottingham.ac.uk/id/eprint/1860 25.

37 Puch-Solis *et a*l 2012 http://eprints.nottingham.ac.uk/id/eprint/1860 25, 86.

38 *R v Reed and Reed; R v Garmson* [2010] 1 Cr App R 23; [2009] EWCA Crim 2698 (hereafter the *Reed* case).

39 The *Reed* case para [72].

40 Puch-Solis *et a*l 2012 http://eprints.nottingham.ac.uk/id/eprint/1860 73.

41 Lieutenant Colonel Sharlene Otto, Sub-section Commander *E-mail Correspondence: DNA Reporting Biology SAPS FSL* (18 May 2020).

42 Meintjes-van der Walt *DNA in the Courtroom*, cited in *Adams v S* 2012 ZAECGHC 55 (25 June 2012) para 5.

43 Meintjes-van der Walt 2010 *SACJ* 373.

The DNA sample should be properly collected from the crime scene and sealed. It should then be properly referenced, transported and submitted to the responsible forensic science laboratory for proper analysis of the sample. The conditions in which DNA is kept or stored should be up to standard to avoid cross-contamination of samples due to handling errors.[44] There is a need for a proper system of bagging, labelling the samples as well as for recording that the samples were preserved at each stage of the process and are free of any contamination.

Lukis Anderson, a person with a nonviolent crime record, was arrested by the Californian police in 2012 and charged with the murder of Raveesh Kumra.[45] After Kumra had been murdered at his house outside San Jose, biological matter, found under his fingernails, was matched to the DNA of Anderson, whose profile had been retained in a database. After five months in gaol, Anderson's lawyer found records to indicate that, at the time of Kumra's death, Anderson was in detox in a hospital close to Kumra's mansion. It turned out that paramedics treated Anderson earlier on the night of Kumra's murder and, when responding to a distress call from Kumra's house, they inadvertently transferred Anderson's DNA to Kumra by means of an oxygen monitoring device which made contact with Kumra's hand.[46]

According to Taylor *et al*, contamination could be as a result of a primary, secondary or tertiary transfer of DNA.[47] Improved assay sensitivity has led to a situation where successful DNA results can be harvested from even one cell. This has raised concerns regarding the possibility of the transfer of DNA from person to person or from a person to an object.[48]

The process whereby DNA deposited from one person to another person or to an object is referred to as primary DNA transfer. When DNA is transferred from a source to another person or object via an intermediary, this phenomenon is called secondary transfer. In an instance where DNA is transferred from a person to another person or object and then from this intermediary to yet another person or object, this process causes background DNA as a result of tertiary transfer of DNA.[49] Goray and colleagues note that it is possible to detect a biological sample that has been

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44 De Wet, Oosthuizen and Visser 2011 *PELJ* 181.

45 Shaer 2016 https://www.theatlantic.com/magazine/archive/2016/06/a-reasonable-doubt/480747.

46 Shaer 2016 https://www.theatlantic.com/magazine/archive/2016/06/a-reasonable-doubt/480747.

47 Taylor *et al* 2016 *Forensic Sci Int: Genet* 34.

48 Goray, Mitchell and Van Oorschot 2010 *Leg Med* 117-120.

49 Goray, Mitchell and Van Oorschot 2010 *Leg Med* 117-120.

transferred several times and that such a sample could appear as a component in a DNA mixture.[50]

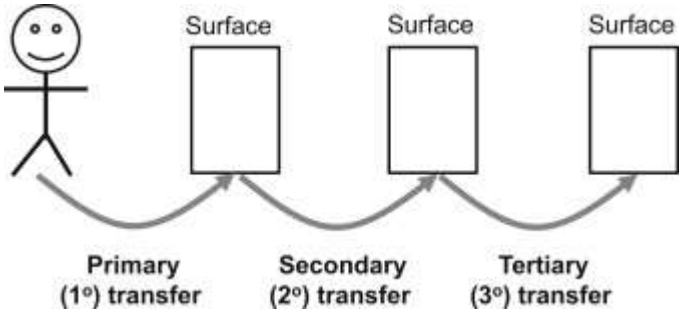

Fig 1 Showing primary, secondary and tertiary transfer[51]

Any contamination or the occurrence of any irregularity should be prevented when handling the DNA sample.[52] Goode[53] argues that handling errors and contamination can lead to false inclusion (full match) and therefore inaccurate results. Observing anti-contamination measures therefore is important to maintain the potential probative value of DNA profiles and to avoid errors in the criminal justice system.

5 The accuracy of the reading and the interpretation of the profile

The potential for a subjective interpretation of complex mixtures was illustrated by Itiel Dror, a University College London, cognitive neuroscientist, and Greg Hampikian, a professor in criminal justice and biology, at Boise State University.[54] In 2010 Dror and Hampikian scrutinised the records of a rape trial conducted in Georgia in 2002. Crucial evidence against the accused stemmed from the evidence of a co-accused who gave evidence to ensure a reduced sentence.[55]

In that case it was submitted by two forensic scientists that sperm found inside the victim, indicated that the accused could not be excluded as a contributor to that particular mixture, which was an indication that the DNA

50 Goray, Mitchell and Van Oorschot 2010 *Leg Med* 117-120. See also Goray et al 2010 *Forensic Sci Int: Genet* 62-67.

51 Butler and Hill 2010 https://worldwide.promega.com/resources/profiles-in-dna/2010/scientific-issues-with-analysis-of-low-amounts-of-dna/.

52 Forensic Science Regulator 2016 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/536827/FSR-anti-contamination.pdf.

53 Goode 2002 *Adel L Rev* 45-56.

54 Dror and Hampikian 2011 *Sci Justice* 204-208.

55 Dror and Hampikian 2011 *Sci Justice* 204.

of the accused constituted a possible match. As a consequence of this, the accused was found guilty.[56]

Dror and Hampikian asked seventeen experienced laboratory technicians, who were not familiar with the context of the investigation, to establish whether DNA of the accused was indeed included in the mixture.[57] The outcome of this experiment indicated that just one technician concluded that the accused could not be excluded as a contributor to the mixture, while twelve technicians found that the accused should be excluded as a contributor and four found that the evidence of the analysis was inconclusive concerning the possibility that the accused could have been a contributor.[58] This means that if the findings of these seventeen technicians had been available to the court in 2002, the court might have reached a different verdict.[59] Dror and Hampikian contextualised the significance of this experiment by quoting the DNA pioneer, Peter Gill, who once stated: "If you show 10 colleagues a mixture, you will probably end up with 10 different answers" concerning the identity of a contributor.[60]

DNA evidence was also considered in *S v Maqhina*[61] (hereafter the *Maqhina* case), where the court held that, "in situations where the accused's guilt depends solely on the results of scientific analysis – it is important that the testing process, including the control measures applied, be executed and recorded with such care that it can be verified at any time by an objective expert and trial court".[62]

Several shortcomings of the DNA evidence were pointed out in the *Maqhina* case, and the court failed to find the objective reliability of the DNA results presented to the court:

(a) The expert of the forensic science laboratory had not followed appropriate standard protocols.[63]

(b) The person(s) conducting the tests were not suitably qualified.

56 Dror and Hampikian 2011 *Sci Justice* 205.
57 Dror and Hampikian 2011 *Sci Justice* 207.
58 Dror and Hampikian 2011 *Sci Justice* 207.
59 Dror and Hampikian 2011 *Sci Justice* 207.
60 Dror and Hampikian 2011 *Sci Justice* 207.
61 *S v Maqhina* 2001 1 SACR 241 (T) (hereafter the *Maghina* case).
62 *Maqhina* case paras 251H-I.
63 *Maqhina* case para 250F.

(c) The expert of the forensic science laboratory had failed to run certain duplicate tests, which according to the defence expert, made it impossible to determine the reliability of the test.[64]

(d) The forensic science laboratory was not an accredited laboratory.[65]

Martin[66] provides suggestions to limit shortcomings of DNA evidence. He suggests that the following requirements be met:

(a) The condition of any instrumentation employed must adhere to proper procedures.

(b) The person(s) interpreting the results must be suitably qualified.

Roth[67] explains that "cold hit" cases occur when the entirety of the state's case against the suspect, excluding his prior conviction, is a DNA profile match.[68] The development of national DNA databases has made it possible for "cold hit" cases to increase and for a prosecution to be based solely on a DNA match.[69] In a cold hit case, police develop a DNA profile from an evidence sample but with no identified suspect.[70] The DNA offender database allows the police to try and solve the case by running the DNA sample through the database to see if there is a matching offender profile. If the search yields a matching result, an offender is identified and becomes a suspect, through a cold hit. An increase in cold hit cases has evoked the question of whether DNA evidence alone is sufficient to convict an accused. Some of the possible complexities and complications which could arise from cold hit cases are mentioned below with reference to *People v Puckett*[71] (hereafter the *Puckett* case).

Two kinds of DNA profiles are included in the DNA database, namely known profiles and crime scene profiles. The known profiles originate from sources such as voluntary contributions, on the one hand, and on the other hand, from compulsory sources such as from arrestees in specified cases and from specified convicted persons.[72] SAPS crime scene technicians collect

64 *Maqhina* case para 251C.
65 *Maqhina* case paras 251C-D.
66 Martin 1998 *De Rebus* 68.
67 Roth 2010 *NYU L Rev* 1132.
68 Roth 2010 *NYU L Rev* 1132.
69 Roth 2010 *NYU L Rev* 1135.
70 Roth 2010 *NYU L Rev* 1135.
71 *People v Puckett* No A121368 (Cal Ct App, 18 April 2009) (hereafter the *Puckett* case).
72 Sections 15I and 15J of the *Criminal Law (Forensic Procedures) Amendment Act* 37 of 2013.

crime scene profiles which, depending on factors such as the quality of the sample and the clarity of the connection between the sample and the crime, could be used as evidence to solve unsolved cases.[73]

In a case where an accused person is identified through DNA match evidence, there will likely be other evidence before the court that establishes the crime and its nature.[74] The other evidence, such as eyewitness identification evidence will narrow down the suspect population If there are twenty people in a country with matching DNA, the fact that there is no other evidence will leave open the possibility that some individual, not the accused, could have left his or her DNA at the crime scene in question or could be the perpetrator of the crime in question. The mere fact that there is a match between the suspect and the sample does therefore not necessarily mean that that individual committed the crime. The *Puckett* case is an example of the emerging phenomenon of "cold hit" cases. In 1972 a nurse was sexually assaulted and stabbed to death. The police collected forensic evidence, but in the absence of DNA typing, a proper DNA investigation was not possible at the time. However, more than thirty years later, DNA samples related to this case were run through the state database.[75] Sperm found on the body of the deceased provided a DNA partial match, which linked John Puckett, a seventy-year-old man confined to a wheelchair, to the crime.

No direct evidence other than the DNA evidence hit and Puckett's presence in the Bay area at the time when the victim was killed, linking him to the crime committed in 1972, was presented to the court at the trial held in 2008. The jurors were not informed that sharing alleles at nine loci is not uncommon.[76] It was also not explained to the jurors that, even when the government's probabilistic statistic is used, the crime scene evidence in this instance would be matched by around forty other citizens in California.[77] Most notably, it was not brought to the attention of the jurors that even according to the database match statistics which are endorsed by the authoritative *The Evaluation of Forensic DNA Evidence* 1996 report,[78] there

73 Section 15H of the *Criminal Law (Forensic Procedures) Amendment Act* 37 of 2013.
74 Ligertwood 2011 *Syd LR* 498-499.
75 Murphy 2015 https://www.theatlantic.com/science/archive/2015/10/the-dark-side-of-dna-databases/408709/.
76 Until 2014 South Africa also tested nine loci with Profiler Plus.
77 Murphy 2015 https://www.theatlantic.com/science/archive/2015/10/the-dark-side-of-dna-databases/408709/.
78 National Research Council *Evaluation of Forensic DNA Evidence*.

would be a match probability of one in three when a government search is conducted.[79]

Some scholars have raised concerns that DNA alone (in cold hit cases) may carry the risk of laboratory errors, coincidental matches, contamination or inaccurate results.[80] In cold hit cases, it is vital to rule out the possibility of laboratory contamination and interpretative errors to avoid a wrongful conviction.

6 The proper role of probabilistic evidence and reasoning in the evaluation of evidence

In many cases it is not the technology or the science but the supervising biologist's subjective interpretation of the results that is the crucial factor in assessing whether a suspect sample and a crime scene sample "match". What she/he is doing, is looking at the Profiler Plus or AmpFlSTR Identifiler Plus or AmpFlSTR Identifiler Direct and concluding whether there is a match or not. In some cases, the readings will be clear and conclusive, some will not be so clear and in others they will be far from clear.[81] Where professional judgement and expertise are required to be exercised, there is often fertile ground for cross-examination such as in the instances mentioned below:

a) where there is only a partial match.[82]

b) where the reading is weak.[83]

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79 Murphy 2015 https://www.theatlantic.com/science/archive/2015/10/the-dark-side-of-dna-databases/408709/.

80 Sangero and Halpert 2007 *Jurimetrics J* 43-94; Roth 2010 *NYU L Rev* 1130-1185.

81 Haesler 2005 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx.

82 "A partial match reduces the opportunity for the full application of the statistical equation used to calculate the likelihood of a 'match', known as the 'product rule'. A partial match creates the chance that the missing portion may yield a result that would exclude the suspect. At a certain point the match probability figures become so low as to be meaningless as corroboration." See Haesler 2005 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx.

83 "A weak reading has similar problems to that of the partial match. It is often impossible to tell the difference between a true reading at a locus and a glitch on the graph brought about by the testing process. As a result, alleles may be wrongly counted or missed altogether. Most labs have a minimum peak height below which they will not hazard an assessment. On occasion, a match will be given despite a low peak height. Examination of low peaks can also disclose a potential extra contributor to a sample, raising the possibility that this person may be the true culprit, or the possibility of secondary transfer.

c) where the crime scene sample is a mixture of more than one person's DNA.[84]

d) where there may be contamination.[85]

e) where the DNA may not have been directly deposited, such as in the case of secondary transfer.[86]

f) where there is the possibility that the results were skewed by mutation.[87]

Some of the risks regarding the statistical significance of a DNA match are only now becoming apparent. Mathew Goode observes:[88]

> [th]e highly subjective nature of the mathematical process remains concealed behind the apparent certainty of a bald statistic.

There is also a phenomenon known as a stutter, where an artefact of testing appears as a peak, mimicking an allele's graph peak. Trained analysts claim to be able to ascertain the difference between an allele and a stutter. There are certain signals to look out for, but that being said, we all look for what we want to see. Stutters have been, and will continue to be, be interpreted as peaks with the consequence of a false match or false exclusion. Similar problems can arise if only a single reading is found at one locus. A single reading can mean the alleles at that point are the same. It can also mean something has dropped out or not shown up on the graph (known as allelic drop-out or a null allele). A false positive or false negative reading can result." See Haesler 2005 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx.

84 "DNA mixtures are derived from biological samples which consist of at least two individuals' DNA in different proportions. They are frequently obtained in criminal scenes and may contain DNA information from the suspect. Thus, the reliable interpretation of DNA mixture is significant for forensic application." See Bieber *et al* 2016 *BMC Genet* 2-3.

85 "Contamination is defined as the inadvertent addition of an individual's DNA during or after collection of the evidence sample and may thus occur both at the crime scene and in the laboratory." Anon date unknown https://www.google.com/search?q=what+is+dna+contamination&rlz=1C1GGRV_enZA815ZA815&oq=WHAT+IS+DNA+CONTAMINATION&aqs=chrome.0.0l3.15554j0j4&sourceid=chrome&ie=UTF-8. Secondary DNA transfer is an extension of this process, where DNA is transferred to an object or person through an intermediate.

86 See Ryding 2019 https://www.news-medical.net/life-sciences/Secondary-Transfer-of-DNA-in-Forensics.aspx; Anon date unknown https://www.google.com/search?q=what+is+dna+contamination&rlz=1C1GGRV_enZA815ZA815&oq=WHAT+IS+DNA+CONTAMINATION&aqs=chrome.0.0l3.15554j0j4&sourceid=chrome&ie=UTF-8.

87 Haesler 2010 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_local_court_csi_effect.aspx.

88 Goode 2002 *Adel L Rev* 66-67.

Haesler emphasises that in cases where there is no evidence other than the DNA evidence or in instances where DNA evidence is of crucial importance, extreme caution should be exercised when such evidence is evaluated.[89] *R v Forbes* is a case where DNA was used to prove sexual assault.[90] Forbes was convicted based on DNA evidence alone even though the complainant could not identify him from a photo board display and despite his denial of guilt and the fact that he had an alibi.[91]

Roth explains that when source probabilities are high enough, this results in a transformation of certainty rather than probability which prompts an assumption that the evidence is strong.[92] Probabilistic reasoning plays an important role in criminal proceedings. Individuals involved in the adjudication of criminal cases should be able to comprehend and be able appropriately to deal with probability, as failure to do so can result in a miscarriage of justice.

Muller[93] argues that understanding probabilities is difficult when, for example, evidence and innocence are the objects being considered by the courts. He gives the following example:[94]

> At a crime scene, a sample of biological material is collected from which a DNA profile of the perpetrator is obtained. Forensic experts estimate that the probability that a randomly chosen person from the population would have the same DNA profile as that of the DNA sample obtained from the crime scene is one in 2 million. (We assume the laboratory work was accurately performed.) Eventually someone is found whose DNA profile matches the DNA profile of the sample obtained at the crime scene. Suddenly this person becomes both suspect and defendant in a criminal case.
>
> Let *A* and *B* be the following events:
>
> *A*: The accused has the DNA profile of the perpetrator.
>
> *B*: The accused is innocent.

89 Haesler 2010 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_local_court_csi_effect.aspx.

90 *R v Forbes* [2009] ACTCA 10 (hereafter the *Forbes* case).

91 *Forbes* case. His leave to appeal failed. See *Forbes v The Queen* [2010] HCA Trans 45.

92 Roth 2010 *NYU L Rev* 1158-1159.

93 Muller 2012 *Stell LR* 371.

94 Muller 2012 *Stell LR* 371.

According to Muller, two conditional probabilities can be considered in this example, namely:[95]

> *P(A|B)* = The probability of *A*, given *B* (i.e. the probability that the accused has the DNA profile of the perpetrator, given the fact that he is innocent).
>
> *P(B|A)* = The probability of *B*, given *A* (i.e. the probability that the matches that of the perpetrator accused is innocent, given the fact that his DNA profile).

A failure to distinguish between the two probabilities can amount to serious consequences or errors in handling the case and in the criminal justice system.

The "prosecutor's fallacy" is committed when the rarity of the DNA profile is equated to the likelihood of guilt. Expressing the statistical conclusion in the wrong terms may mislead the bench. Discussing the English case *Doheny and Adams v The Queen* [1997] 1 Cr App R 369 (hereafter the *Doheny* case), Brown and Meintjes-van der Walt explain as follows:[96]

In the *Doheny* case the court stressed the need to avoid evidence that is compromised by the "prosecution's fallacy":

> 1) Only one person in a million will have a DNA profile which matches the stain;
>
> 2) The accused has a DNA profile which matches the stain;
>
> 3) Ergo, there is a million to one probability that the accused left the crime stain and is guilty of the crime.
>
> The error in the lawyer's fallacy arises out of the confusion of two conditional probabilities:
>
> 1) The probability that a DNA sample taken from an innocent person matches that found at the murder scene GIVEN THAT the person is innocent.
>
> 2) The probability that a person is innocent GIVEN THAT their DNA sample matches that found at the scene of the crime.
>
> These two probabilities are NOT the same and it is clearly the second one that is of interest in determining whether a guilty verdict should be returned or not. The first probability is the 1 in a million that is given by the prosecution's expert witness. He is saying that 1 in a million people have a DNA sample like that found at the scene of the crime. Thus if an innocent person is tested there is a one in a million chance that his/her DNA sample will match.

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95 Muller 2012 *Stell LR* 371.

96 Brown and Meintjes-van der Walt 2007 *JJS* 8. See also Meintjes-van der Walt *DNA in the Courtroom* 101.

> Note that in the lawyer's summing up he in effect claims that the probability that the defendant is innocent is 1 in a million. In other words, he is claiming that the SECOND probability described above is 1 in a million. This is NOT the case.
>
> The error was also committed in *R v Deen [The Times* 10 January 1994] where the expert, after stating that 'the likelihood of this being any other man than [the accused] is one in 3 million,' concluded by saying 'My conclusion is that the semen originated from [the accused].'

Brown and Meintjes-van der Walt explain that the expert committed an error that was accepted by the jury. The expert confused two questions, namely:[97]

> (i) What is the probability of finding the evidence, given that the accused is innocent?
>
> (ii) What is the probability that the accused is innocent, given the evidence?

For example, if the evidence of the DNA expert that the chance

> of finding the matching profiles if this semen (in the crime stain) had originated from a man in the general population other than the accused is 1 in 5 million and the prosecutor or the judge were to translate this into any of the following statements:
>
> - the likelihood that the accused is guilty is 5 million to 1;
> - the likelihood that the accused is innocent is 5 million to 1;
> - the semen is 5 million times more likely to have come from the accused than from any other man;
> - the chance or likelihood that the sample came from someone else is 1 in 5 million;
> - it is 5 million to 1 against that a man other than the accused left the semen,

then these statements would be wrong. All the statements referred to above are misleading and require other than the expert's findings of a match.[98]

The following three points should be considered to avoid a situation where statistical evidence is confused with the probability of guilt:

a) It would be erroneous to decide the probability of the accused being the source of the incriminating DNA, merely based on a statistical interpretation of the significance of a DNA match.

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97 Brown and Meintjes-van der Walt 2007 *JJS* 7-8.
98 Brown and Meintjes-van der Walt 2007 *JJS* 7-8.

b) The fact-finder could, however, utilise the statistical evidence interpretation proffered by an expert, when deciding whether the accused was, beyond a reasonable doubt, the source of the incriminating DNA.

c) Although it cannot be denied that statistical evidence is strong evidence to support a decision that incriminating evidence originated from an accused in question, it should not be assumed to be direct evidence per se. Statistical evidence should always be considered and interpreted in the context of all evidence before the court.[99]

Butler remarks:[100]

> It is important to realise what a random match probability is not. It is not the chance that someone else is guilty or that someone else left the biological material at the crime scene. Likewise, it is not the chance of the defendant being guilty or the chance that someone else in reality would have that same genotype. Rather, a random match probability is the estimated frequency at which a particular STR profile would be expected to occur in the population. This random match probability may also be thought of as the theoretical chance that if you sample one person at random from the population, they will have the particular profile in question.[101]

There could be three possible explanations when the STR profiles of two DNA samples constitute a perfect match:

a) The material collected from the crime scene indicates that it originated from the suspect.[102]

b) Another person whose DNA profile is identical to that of the suspect is the source of the material.[103] This could be the result of the fact that

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99 *R v Karger* (2001) 83 SASR 135 para 16 and 17 (hereafter the *Karger* case). In the United Kingdom suggested guidelines can be found in *Doheny and Adams v The Queen* [1997] 1 Cr App R 369 (the *Doheny* case) and in the Northern Territory in *Latcha v R* (1998) 104 A Crim R 390 (hereafter the *Latcha* case). The Supreme Court of British Columbia has suggested that before DNA evidence is presented to a court it should be made sufficiently clear that: "the estimates are not intended to be precise; they are the products of mathematical and scientific theory not concrete facts; they do not purport to define the likelihood of guilt; they should only be used to form a notion of the rarity of the genetic profile of the accused; and the DNA evidence must be considered along with all the other evidence in the case relating to the issue of identification".

100 Butler *Forensic DNA Typing, Biology, Technology and Genetics of STR Markers.*

101 Butler *Forensic DNA Typing, Biology, Technology and Genetics of STR Markers*.500.

102 The Royal Society 2017 http://www.rse.org.uk/wp-content/uploads/2017/11/DES 4928_2_Law-primers-reports_DNA-analysis_WEB.pdf.

103 The Royal Society 2017 http://www.rse.org.uk/wp-content/uploads/2017/11/DES 4928_2_Law-primers-reports_DNA-analysis_WEB.pdf.

normally a limited number of loci are tested. Before 2014, South Africa tested only nine loci plus Amelogenin, the sex marker.[104] Currently, South Africa tests sixteen loci and Amelogenin.[105]

c) Errors such as accidental sample switches could have resulted in a false-positive result:

The match probability is an estimate of the likelihood of observing that profile if someone other than, and unrelated to, the suspect was the source of the DNA.[106]

A standard report prepared by the South African Police Service Forensic Science Laboratory (SAPS FSL), for example, reads that "The most conservative occurrence for the DNA result from jacket "BA" that can be calculated is 1 person in every 12 000 trillion people". It should be noted that:[107]

> [t]he final statistical calculation … does not prove uniqueness, but provides strong support for the hypothesis (*without taking other evidence into account*) that the DNA from the evidence sample originates from the matched individual. The profile frequency calculation *does not apply to closely related individuals.* (Emphasis added).

7 Mixtures

Advances in science and technology have resulted in extreme sensitivity in DNA detection.[108] In order to generate a DNA profile, forensic experts, in the past, needed a large DNA sample. At present a DNA profile can be constructed from a minute sample such as skin cells deposited by a person merely touching something or somebody. Forensic experts can now analyse DNA mixtures containing DNA from several people. However, trace amounts of DNA, including the "touch DNA" left behind when someone touches an object, can be far more difficult to interpret reliably than the DNA

104 Meintjes-van der Walt and Knoetze 2015 *SACJ* 137.

105 Lieutenant Colonel Sharlene Otto, Sub-section Commander *E-mail Correspondence: DNA Reporting Biology SAPS FSL* (18 May 2020).

106 See The Royal Society 2017 http://www.rse.org.uk/wp-content/uploads/2017/11/DES4928_2_Law-primers-reports_DNA-analysis_WEB.pdf.

107 The Royal Society 2017 http://www.rse.org.uk/wp-content/uploads/2017/11/DES4928_2_Law-primers-reports_DNA-analysis_WEB.pdf.

108 "We often shed small amounts of DNA when we talk, sneeze and touch things. As a result, many surfaces are likely to contain mixtures of minute amounts of DNA from several people. These mixtures have always been present at crime scenes, but when sensitivity was lower, they would not have been detected or, if they were, labs would not have attempted to interpret them. That is no longer the case". Rich Press 2019 https://www.nist.gov/featured-stories/dna-mixtures-forensic-science-explainer.

evidence previously available for analysis.[109] The extremely complex nature of the analysis and interpretation of minute DNA traces, gives rise to considerable danger when the importance of the DNA evidence is inappropriately afforded greater weight than other evidence.[110]

8 DNA transfer

There are situations where there is only one potential DNA donor and where transfer occurs from the offender to the victim or to the scene of the crime.[111] However, in some situations there could be two or more potential donors of DNA. DNA transfer, as is briefly indicated above, may occur due to primary transfer[112] as a result of direct contact with an object or person); secondary transfer, that is indirect contact – not related to the crime;[113] tertiary transfer[114] and laboratory contamination.[115]

In the Australian case of *R v Jama*,[116] an unconscious woman was found in a toilet cubicle. A medical examination found one intact sperm and 15 sperm-heads which linked this victim to Farah Jama's DNA and he was subsequently convicted of murder on the strength of DNA evidence only.[117] After sixteen months of incarceration, Jama's conviction was quashed when it became clear that the DNA profile had been transferred by contamination.[118] Jama had earlier engaged in sexual intercourse with another woman who, 28 hours before the incident for which Jama was convicted, was examined by the same medical doctor who examined Jama's alleged victim. There was a possibility that contamination could have happened in the medical facility or even in the laboratory where the samples were processed.[119]

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109 Rich Press 2019 https://www.nist.gov/featured-stories/dna-mixtures-forensic-science-explainer.
110 Gill *Misleading DNA Evidence* 1-158.
111 Puch-Solis *et a*l 2012 http://eprints.nottingham.ac.uk/id/eprint/1860 57.
112 Gill 2016 *Forensic Sci Int: Genet* 10.
113 Gill 2016 *Forensic Sci Int: Genet* 10.
114 Fonneløp, Egeland and Gill 2015 *Forensic Sci Int: Genet* 155.
115 Gill 2016 *Forensic Sci Int: Genet* 10.
116 See 2010 http://www.parliament.vic.gov.au/papers/govpub/VPARL2006-10No301.pdf (hereafter the Vincent Report).
117 Vincent Report 13.
118 Vincent Report 39. See also *R v Jama* [2009] VSCA [CA No 764 of 2008] (7 December 2009).
119 Vincent Report 59-64.

Fitzgerald v The Queen[120] refers to a burglary during which a victim was murdered and during which another victim sustained serious brain injuries. DNA deposited on a didgeridoo, which was left at the crime scene, linked Fitzgerald to the crime and consequently he was convicted of murder even though no other evidence linked him to the murder. Fitzgerald appealed his conviction and contended that the verdict was unreasonable as his DNA could have been transferred to the didgeridoo as a result of secondary transfer.[121] His appeal succeeded. No direct evidence of harm caused to the deceased or the other victim was presented to the court and the prosecution built the case against the accused by using evidence based on a DNA sample collected from a didgeridoo (an Aboriginal musical instrument) left at the crime scene in order to prove that the accused had been involved in the attack.

In the Italian case of Knox and Sollecito concerning the 2007 murder of Knox's roommate, Kercher[122] demonstrates the complex nature of DNA evidence. The first suspect, Guede's multiple DNA profiles were recovered from the room where the victim was murdered and from the victim's vaginal swab. He had no legitimate reason to be on the premises and he pleaded guilty, but implicated Knox and Sollecito.[123] DNA profiles pertaining to Knox were recovered away from the crime scene, that is on the blade of a knife found in a drawer in Sollecito's flat and in the bathroom she shared with the victim.[124] Sollecito's DNA profile was found on the victim's bra-clasp, found at the crime scene.[125] The DNA evidence against Guede was overwhelming

120 *Fitzgerald v The Queen* [2014] HCA 28 (13 August 2014) (hereafter the *Fitzgerald* case).

121 The *Fitzgerald* case paras 27, 29. Secondary transfer, as is referred to with regard to Fitzgerald's case discussed above, is also illustrated in Adam Scott's case. Subsequent to a wrongful arrest, Scott was charged with rape. In October 2011 an alleged "spitting incident" took place in Exeter and the British Transport Police took a saliva sample from Scott and submitted it for processing. Coincidentally, at the same time as the Scott incident the police took semen swabs from a woman who had been attacked in Manchester, and also sent these samples to the same laboratory where Scott's saliva sample was deposited. When Scott's sample was run through the UK's DNA database, a partial match was found between Scott's sample and the sample obtained from the attacked woman. It subsequently emerged that the plastic tray used for the saliva DNA samples was also used in the process of running DNA samples from the rape victim. After spending five months in jail on remand, he was released after it was found that he was "the innocent victim of an avoidable contamination". Rennison 2012 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/118941/dna-contam-report.pdf.

122 Gill 2016 *Forensic Sci Int: Genet* 9-18.

123 Gill 2016 *Forensic Sci Int: Genet* 10.

124 Gill 2016 *Forensic Sci Int: Genet* 11, 15.

125 Gill 2016 *Forensic Sci Int: Genet* 16.

as his DNA was found at numerous places at the crime scene, including the victim's clothing. Knox and Sollecito were convicted but after a series of trials they were finally acquitted in 2015 due to lack of evidence. The DNA profiles that were attributed to them could have been transferred by secondary transfer not related to the commission of the crime.[126]

Cale *et al* conducted an experiment regarding secondary DNA transfer induced by a handshake.[127] Persons were asked to engage in handshakes immediately before handling individual knives.[128] Afterwards the DNA of the person who had held the knife was found in virtually each one of the cases concerned. However, in 85% of the experiment cases, the DNA profiles of persons who did not actually touch the knife were also found on the knife. Furthermore, the experiment revealed that in 20% of the test cases, the DNA of a person who did not actually touch the knife, was registered as the primary, and in some cases, as the only DNA contributor.[129]

As minute quantities of DNA trace material, such as non-visible staining, can at present be captured and analysed, the exact source of a DNA sample is no longer regarded as the most important question. The question "whose DNA is this?" has moved to the crucial question "how did it get there?"[130]

9 Conclusion

The discussion above, indicates that relying solely on DNA evidence to convict an accused person, can be prejudicial. The *Bokolo* case in South Africa[131] briefly discussed above, and several cases in other jurisdictions[132] have grappled with the problem of weighing up DNA evidence only, in the absence of other corroborating evidence.

In the absence of any other evidence, especially in cold hit cases, it is difficult to conclude that the accused is the actual criminal[133] and relying solely on DNA evidence might result in wrongful convictions.[134] The risks of false-positive matches increases as the size of the database increases. This

126 Gill 2016 *Forensic Sci Int: Genet* 10, 15.
127 Cale *et al* 2016 *J Forensic Sci* 201.
128 Cale *et al* 2016 *J Forensic Sci* 202.
129 Cale *et al* 2016 *J Forensic Sci* 203.
130 Biedermann *et al* 2016 *Front Genet* 1.
131 See the *Bokolo cas*e.
132 The *Jama* case; the *Fitzgerald* case; the *Forbes* case.
133 Roth 2010 *NYU L Rev* 1145.
134 Sangero and Halpert 2007 *Jurimetrics Jl* 43-94. See also Olaborede and Meintjes-van der Walt 2020 *PELJ* 1-38.

fact emphasises why, in addition to considering DNA evidence, the non-DNA evidence must also be duly considered.[135]

The conclusions reached in this article are supported by court decisions in other jurisdictions, not discussed above due to space restrictions.

In South Australia, the general view is that a jury can convict if the DNA is properly evaluated in the context of all other evidence.[136] However, in some cases where DNA was the sole evidence of identity presented in courts, this has led to miscarriages of justice.[137] The Victoria's Court of Appeal in Australia has held that DNA profiling establishes no more than that the accused could be the offender.[138] This point is taken up in Victoria's Judges' Bench Notes.[139] However, this did not prevent Mr Jama's conviction[140] as is briefly indicated above.

The Scottish courts have a rather narrow view of the DNA evidence.[141] In *Maguire v HM Advocate*[142] the court held that in the absence of an innocent explanation, even DNA found on a portable item such as a woollen mask, is sufficient to convict.

In England, in *R v Adams*[143] the court stated that there is no principle of law that DNA evidence of itself is incapable of proving guilt[144] and in the *Watters* case, it emerged that there is no rule about when it is safe to leave statistical calculations to a jury.[145] A judge can, however, instruct a jury that, where the DNA evidence stands alone, they should not convict.[146] On 11 June 1999, the Crown Court of Liverpool convicted and sentenced Lashley on charges of robbery and the illegal possession of an imitation firearm. The conviction was solely based on DNA evidence obtained from a cigarette butt found at the crime scene. Lashley appealed his conviction. On appeal Lord

135 Amankwaa and McCartney 2019 *Forensic Sci Int: Synergy* 45-55.
136 Haesler "Issues in Gathering, Interpreting and Delivering DNA Evidence" 4-5.
137 The Vincent Report. See also Haesler "Issues in Gathering, Interpreting and Delivering DNA Evidence" 7.
138 *R v Noll* [1999] 3 VR 704 (hereafter the *Noll* case) para 25.
139 See para 4.13.2.2 "Charge: DNA Evidence", quoted in Haesler 2010 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_local_court_csi_effect.aspx.
140 The *Jama* case. See also Vincent 2010 http://www.parliament.vic.gov.au/papers/govpub/VPARL2006-10No301.pdf.
141 Haesler "Issues in Gathering, Interpreting and Delivering DNA Evidence" 5.
142 *Maguire v HM Advocate* [2003] SLT 1307 (hereafter the *Maquire* case).
143 *R v Adams* [1996] 2 Cr App R 467(hereafter the *Adams* case).
144 The *Adams* case 469.
145 *R v Watters* [2000] EWCA 89 (hereafter the *Watters* case).
146 *The Reed* case).

Justice Kennedy in the England and Wales Court of Appeal (UK)[147] referred to "the difficulty in this particular case of relying on DNA evidence alone in circumstances when there was no other evidence to show that the applicant at that material time was in the Liverpool area".[148] The appeal was upheld. The significance of DNA depends on the evidence in the individual case and how it is to be assessed depends critically upon what else is known about the accused.[149] Following on the Lashley appeal case, the Crown Prosecution Service confirmed in its guidelines that "DNA profiling is not a fool proof science".[150] The guidelines determined that "a suspect should not be charged solely based on a match between his DNA profile and a DNA profile found at the scene of the crime unless there are compelling reasons to do so".[151] This would indicate that a link between an accused person and the scene of the crime, is essential.[152] These Crown Prosecution Service guidelines urge criminal justice practitioners to be constantly aware of the possibility that DNA evidence is potentially open to abuse.

In South Africa, there is no formal bar to a conviction solely based on DNA evidence.[153] Case law[154] has shown that courts can convict an accused based on DNA evidence alone if the evidence is relevant, admissible and reliable in the particular circumstances of the case. Courts should bear in mind that the calculated statistic is not the odds that the accused was the perpetrator of the crime. It is merely an estimate of the chances that another unrelated person belonging to the population to which the suspect belongs, left the evidentiary DNA. All that a DNA match or link shows, is that the accused could be the offender.[155]

147 *R v Lashley* [2000] EWCA 88 (hereafter the *Lashley* case).

148 The *Lashley* case 90.

149 The *Doheny* case 373.

150 Crown Prosecution Service 2004 https://www.cps.gov.uk/sites/default/files/documents/legal_guidance/pdf_000328%2520-%2520%2520DNA%2520Charging%2520Guidance.pdf para 5.1.

151 Crown Prosecution Service 2004 https://www.cps.gov.uk/sites/default/files/documents/legal_guidance/pdf_000328%2520-%2520%2520DNA%2520Charging%2520Guidance.pdf para 5.4.

152 The *Doheny* case 373: "The possibility that two of the only 26 men in the United Kingdom with the matching DNA should have been in the vicinity of the crime will seem almost incredible and a comparatively slight nexus between the defendant and the crime, independent of the DNA, is likely to suffice to present an overall picture to the jury that satisfies them of the defendant's guilt".

153 For example, see the *Bokolo* case.

154 See the *Bokolo* case. Heathfield 2014 *S Afr J Sci* 1-3, citing *S v SMM* 2013 2 SACR 292 (SCA).

155 Haesler 2003 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx.

The strength of DNA is manifested when it is considered within a framework of other evidence. The statistical analysis of DNA tests is impressive and, at times, even intimidating. However, unless there is other corroborating evidence, it cannot be assumed that is safe to convict an accused merely on the strength of ostensibly persuasive statistics.[156]

In cases dealing with a full single DNA profile, DNA evidence alone might be sufficient to convict, if all the proper procedures were followed, such as that the chain of custody is intact, no contamination has occurred and the DNA match is merely a confirmatory match. It might, however, be different when dealing with cold hit cases where a DNA database has been trawled. The DNA match evidence should be undisputed and other evidence should provide corroboration.

The discussion above outlines some of the enormous complexities of DNA evidence and indicates some potential dangers when courts rely on DNA evidence in isolation. The high level of scientific and statistical sophistication involved in DNA evidence should compel the prosecution, the defence, and fact-finders in particular, to take due cognisance of the potential dangers of a conviction based on DNA evidence alone.

A conviction based solely on DNA evidence is dangerous and should be limited and evaluated case by case.

Bibliography

Literature

Amankwaa and McCartney 2019 *Forensic Sci Int: Synergy*
Amankwaa AO and McCartney C "The Effectiveness of the UK National DNA Database" 2019 *Forensic Sci Int: Synergy* 45-55

Bieber *et al* 2016 *BMC Genet*
Bieber FR *et al* "Evaluation of Forensic DNA Mixture Evidence: Protocol for Evaluation, Interpretation, and Statistical Calculations Using the Combined Probability of Inclusion" 2016 *BMC Genet* 1-15

156 Brown and Meintjes-van der Walt 2007 *JJS* 1-43. See also Meintjes-van der Walt *DNA in the Courtroom* 101.

Biedermann *et al* 2016 *Front Genet*
Biedermann A *et al* "Evaluation of Forensic DNA Traces when Propositions of Interest Relate to Activities: Analysis and Discussion of Recurrent Concerns" 2016 *Front Genet* 1-12

Brown and Meintjes-van der Walt 2007 *JJS*
Brown B and Meintjes-van der Walt L "The Use and Misuse of Statistical Evidence in Criminal Proceedings" 2007 *JJS* 1-43

Butler *Forensic DNA Typing, Biology, Technology and Genetics of STR Markers*
Butler JM *Forensic DNA Typing, Biology, Technology and Genetics of STR Markers* 2nd ed (Elsevier Academic Press Burlington 2005)

Cale *et al* 2016 *J Forensic Sci*
Cale CM *et al* "Could Secondary DNA Transfer Falsely Place Someone at the Scene of a Crime?" 2016 *J Forensic Sci* 196-203

Cook *et al* 1998 *Sci Justice*
Cook R *et al* "A Hierarchy of Propositions: Deciding which Level to Address in Casework" 1998 *Sci Justice* 231-239

De Wet, Oosthuizen and Visser 2011 *PELJ*
De Wet S, Oosthuizen H and Visser J "DNA Profiling and the Law in South Africa" 2011 *PELJ* 171-207

Dror and Hampikian 2011 *Sci Justice*
Dror IE and Hampikian G "Subjectivity and Bias in Forensic DNA Mixture Interpretation" 2011 *Sci Justice* 204-208

Findlay *et al* 1997 *Nature*
Findlay I *et al* "DNA Fingerprinting from Single Cells" 1997 *Nature* 555-556

Fonneløp, Egeland and Gill 2015 *Forensic Sci Int: Genet*
Fonneløp AE, Egeland T and Gill P "Secondary and Subsequent DNA Transfer during Criminal Investigations" 2015 *Forensic Sci Int: Genet* 155-162

Gill 2016 *Forensic Sci Int: Genet*
Gill P "Analysis and Implications of the Miscarriages of Justice of Amanda Knox and Raffaele Sollecito" 2016 *Forensic Sci Int: Genet* 9-18

Gill *Misleading DNA Evidence*
Gill P *Misleading DNA Evidence: Reasons for Miscarriages of Justice* (Elsevier Academic Press San Diego 2014)

Goode 2002 *Adel L Rev*
Goode M "Observations on Evidence of DNA Frequency" 2002 *Adel L Rev* 45-77

Goray, Mitchell and Van Oorschot 2010 *Leg Med*
Goray M, Mitchell RJ and Van Oorschot RAH "Investigation of Secondary DNA Transfer of Skin Cells under Controlled Test Conditions" 2010 *Leg Med* 117-120

Goray *et al* 2010 *Forensic Sci Int: Genet*
Goray M *et al* "Secondary DNA Transfer of Biological Substances under Varying Test Conditions" 2010 *Forensic Sci Int: Genet* 62-67

Graham *Presentation and Examination of DNA Evidence*
Graham RH *The Presentation and Examination of DNA Evidence Adduced During Adversarial Trials* (PhD-dissertation University of Leeds 2016)

Haesler "Issues in Gathering, Interpreting and Delivering DNA Evidence"
Haesler A "Issues in Gathering, Interpreting and Delivering DNA Evidence" Unpublished contribution delivered at the *Expert Evidence Conference* (February 2011 Canberra)

Heathfield 2014 *S Afr J Sci*
Heathfield LJ "Policy Required for Entry of DNA Profiles onto the National Forensic DNA Database of South Africa" 2014 *S Afr J Sci* 1-3

Ligertwood 2011 *Syd LR*
Ligertwood A "Can DNA Evidence Alone Convict an Accused?" 2011 *Syd LR* 487-514

Martin 1998 *De Rebus*
Martin C "DNA Profiling" 1998 *De Rebus* 67-68

Meintjes-van der Walt 2010 *SACJ*
Meintjes-van der Walt L "The Chain of Custody and Formal Admissions" 2010 *SACJ* 371-384

Meintjes-van der Walt *DNA in the Courtroom*
Meintjes-van der Walt L *DNA in the Courtroom: Principles and Practice* (Juta Cape Town 2010)

Meintjes-van der Walt and Knoetze 2015 *SACJ*
Meintjes-van der Walt L and Knoetze I "The Criminal Law (Forensic Procedures) Amendment Act 37 of 2013: A Critical Analysis" 2015 *SACJ* 131-162

Muller 2012 *Stell LR*
Muller MA "Handling Uncertainty in a Court of Law" 2012 *Stell LR* 370-380

National Research Council *Evaluation of Forensic DNA Evidence*
National Research Council *The Evaluation of Forensic DNA Evidence* (National Academies Press Washington DC 1996)

Olaborede and Meintjes-van der Walt 2020 *PELJ*
Olaborede A and Meintjes-van der Walt L "The Dangers of Convictions Based on a Single Piece of Forensic Evidence" 2020 PELJ 1-38

Roth 2010 *NYU L Rev*
Roth A "Safety in Numbers? Deciding when DNA Alone is Enough to Convict" 2010 *NYU L Rev* 1130-1185

Sangero and Halpert 2007 *Jurimetrics J*
Sangero B and Halpert M "Why a Conviction should not be Based on a Single Piece of Evidence: A Proposal for Reform" 2007 *Jurimetrics J* 43-94

Semikhodskii *Dealing with DNA Evidence*
Semikhodskii A *Dealing with DNA Evidence: A Legal Guide* (Routledge-Cavendish Abingdon 2007)

Taupin *Introduction to Forensic DNA Evidence*
Taupin JM *Introduction to Forensic DNA Evidence for Criminal Justice Professionals* (CRC Press Boca Raton 2014)

Taylor *et al* 2016 *Forensic Sci Int: Genet*
Taylor D *et al* "Observations of DNA Transfer within an Operational Forensic Biology Laboratory" 2016 *Forensic Sci Int: Genet* 33-49

Case law

Adams v S 2012 ZAECGHC 55 (25 June 2012)

Bokolo v S 2013 ZASCA 115 (18 September 2013)

Doheny and Adams v The Queen [1997] 1 Cr App R 369

Fitzgerald v The Queen [2014] HCA 28 (13 August 2014)

Forbes v The Queen [2010] HCA Trans 45

Latcha v R (1998) 104 A Crim R 390

Maguire v HM Advocate [2003] SLT 1307

People v Puckett No A121368 (Cal Ct App, 18 April 2009)

R v Adams [1996] 2 Cr App R 467

R v Blom 1939 AD 188

R v Difford 1937 AD 37

R v Forbes [2009] ACTCA 10

R v Jama [2009] VSCA [CA No 764 of 2008] (7 December 2009)

R v Karger (2001) 83 SASR 135

R v Lashley [2000] EWCA 88

R v Noll [1999] 3 VR 704

R v Reed and Reed; R v Garmson [2010] 1 Cr App R 23; [2009] EWCA Crim 2698

R v Watters [2000] EWCA 89

S v Maqhina 2001 1 SACR 241 (T)

S v Nyembe 2014 1 SACR 105 (GSJ)

S v Reddy 1996 2 SACR 1 (A)

S v SMM 2013 2 SACR 292 (SCA)

Seboko v S 2009 JOL 23588 (NCK)

Legislation

Criminal Law (Forensic Procedures) Amendment Act 37 of 2013

Internet sources

Aitken, Roberts and Jackson 2010 https://pdfs.semanticscholar.org/004e/55d7a450c0a47f7976e762c06142b5dc03b8.pdf
Aitken C, Roberts P and Jackson G 2010 *Communicating and Interpreting Statistical Evidence in the Administration of Criminal Justice: Fundamentals of Probability and Statistical Evidence in Criminal Proceedings* https://pdfs.semanticscholar.org/004e/55d7a450c0a47f7976e762c06142b5dc03b8.pdf accessed 30 April 2020

Anon date unknown https://www.google.com/search?q=what+is+dna+contamination&rlz=1C1GGRV_enZA815ZA815&oq=WHAT+IS+DNA+CONTAMINATION&aqs=chrome.0.0l3.15554j0j4&sourceid=chrome&ie=UTF-8
Anon Date Unknown *What is DNA Contamination?* https://www.google.com/search?q=what+is+dna+contamination&rlz=1C1GGRV_enZA815ZA815&oq=WHAT+IS+DNA+CONTAMINATION&aqs=chrome.0.0l3.15554j0j4&sourceid=chrome&ie=UTF-8 accessed 18 April 2020

Brenner date unknown http://charlesbrenner.com/profile.htm
Brenner CH date unknown *Forensic Mathematics of DNA Matching* http://charlesbrenner.com/profile.htm accessed 13 April 2020

Butler and Hill 2010 https://worldwide.promega.com/resources/profiles-in-dna/2010/scientific-issues-with-analysis-of-low-amounts-of-dna/
Butler JM and Hill A 2010 *Scientific Issues with the Analysis of Low Amounts DNA* https://worldwide.promega.com/resources/profiles-in-dna/2010/scientific-issues-with-analysis-of-low-amounts-of-dna/ accessed 30 May 2020

Crown Prosecution Service 2004 https://www.cps.gov.uk/sites/default/files/documents/legal_guidance/pdf_000328%2520-%2520%2520DNA%2520Charging%2520Guidance.pdf
Crown Prosecution Service 2004 *Guidance on DNA Charging* https://www.cps.gov.uk/sites/default/files/documents/legal_guidance/pdf_000328%2520-%2520%2520DNA%2520Charging%2520Guidance.pdf accessed 30 May 2020

Forensic Science Regulator 2016 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/536827/FSR-anti-contamination.pdf
Forensic Science Regulator 2016 *The Control and Avoidance of Contamination in Crime Scene Examination Involving DNA Evidence*

Recovery https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/536827/FSR-anti-contamination.pdf accessed 18 April 2020

Haesler 2003 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx
Haesler A 2003 *DNA - An Overview of Testing and the Crimes (Forensic Procedures) Act 2000* https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx accessed 15 August 2020

Haesler 2005 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx
Haesler A 2005 *DNA for Defence Lawyers* https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_for_lawyers.aspx accessed 14 April 2020

Haesler 2010 https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_local_court_csi_effect.aspx
Haesler A 2010 *DNA in the Local Court - The CSI Effect* https://www.publicdefenders.nsw.gov.au/Pages/public_defenders_research/Papers%20by%20Public%20Defenders/public_defenders_dna_local_court_csi_effect.aspx accessed 16 April 2020

Murphy 2015 https://www.theatlantic.com/science/archive/2015/10/the-dark-side-of-dna-databases/408709/
Murphy E 2015 *The Dark Side of DNA Databases* https://www.theatlantic.com/science/archive/2015/10/the-dark-side-of-dna-databases/408709/ accessed 14 April 2020

Puch-Solis *et a*l 2012 http://eprints.nottingham.ac.uk/id/eprint/1860
Puch-Solis R *et al* 2012 *Assessing the Probative Value of DNA Evidence: Guidance for Judges, Lawyers, Forensic Scientists and Expert Witnesses* http://eprints.nottingham.ac.uk/id/eprint/1860 accessed 25 April 2020

Rennison 2012 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/118941/dna-contam-report.pdf

Rennison A 2012 *Report into the Circumstances of a Complaint Received from the Greater Manchester Police on 7 March 2012 Regarding DNA Evidence Provided by LGC Forensic on the Adam Scott Case* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/118941/dna-contam-report.pdf accessed 11 April 2020

Rich Press 2019 https://www.nist.gov/featured-stories/dna-mixtures-forensic-science-explainer
Rich Press 2019 *DNA Mixtures: A Forensic Science Explainer* https://www.nist.gov/featured-stories/dna-mixtures-forensic-science-explainer accessed 15 April 2020

Ryding 2019 https://www.news-medical.net/life-sciences/Secondary-Transfer-of-DNA-in-Forensics.aspx
Ryding S 2019 *Secondary Transfer of DNA in Forensics* https://www.news-medical.net/life-sciences/Secondary-Transfer-of-DNA-in-Forensics.aspx accessed 18 April 2020

Shaer 2016 https://www.theatlantic.com/magazine/archive/2016/06/a-reasonable-doubt/480747
Shaer M 2016 *The False Promise of DNA Testing* https://www.theatlantic.com/magazine/archive/2016/06/a-reasonable-doubt/480747/ accessed 16 May 2020

The Royal Society 2017 http://www.rse.org.uk/wp-content/uploads/2017/11/DES4928_2_Law-primers-reports_DNA-analysis_WEB.pdf
The Royal Society 2017 *Forensic DNA Analysis: A Primer for Courts* http://www.rse.org.uk/wp-content/uploads/2017/11/DES4928_2_Law-primers-reports_DNA-analysis_WEB.pdf accessed 18 April 2020

ThermoFisher Scientific date unknown https://www.thermofisher.com/za/en/home/industrial/forensics/human-identification/forensic-dna-analysis/pcr-amplification-forensic-dna-profiling/identifiler-plus-product-overview.html
ThermoFisher Scientific date unknown *AmpFlSTR Identifiler Kits* https://www.thermofisher.com/za/en/home/industrial/forensics/human-identification/forensic-dna-analysis/pcr-amplification-forensic-dna-profiling/identifiler-plus-product-overview.html accessed 18 April 2020

Vincent 2010 http://www.parliament.vic.gov.au/papers/govpub/VPARL2006-10No301.pdf

Vincent FHR 2010 *Inquiry into the Circumstances that Led to the Conviction of Mr Farah Abdulkadir Jama* http://www.parliament.vic.gov.au/papers/govpub/VPARL2006-10No301.pdf accessed 15 April 2020

Other sources

Lieutenant Colonel Sharlene Otto, Sub-section Commander *E-mail Correspondence: DNA Reporting Biology SAPS FSL* (18 May 2020)

List of Abbreviations

Adel L Rev	Adelaide Law Review
BMC Genet	BioMed Central Genetics
DNA	Deoxyribonucleic Acid
Forensic Sci Int: Genet	Forensic Science International: Genetics
Forensic Sci Int: Synergy	Forensic Science International: Synergy
Front Genet	Frontiers in Genetics
FSL	Forensic Science Laboratory
J Forensic Sci	Journal of Forensic Sciences
JJS	Journal for Juridical Science
Jurimetrics J	Jurimetrics Journal
LCN	Low Copy Number
Leg Med	Legal Medicine
NYU L Rev	New York University Law Review
PCR	Polymerase Chain Reaction
PELJ	Potchefstroom Electronic Law Journal
RMP	Random Match Probability
S Afr J Sci	South African Journal of Science
SACJ	South African Journal of Criminal Justice
SAPS	South African Police Service
Sci Justice	Science and Justice
Stell LR	Stellenbosch Law Review
STR	Short Tandem Repeat
Syd LR	Sydney Law Review
UK	United Kingdom
US	United States