



Legally Scientific?

- a brief history of DNA evidence in the criminal justice system

Science is the search for truth - it is not a game in which one tries to beat his opponent, to do harm to others. - Linus Pauling

Forensic Science in Court

Scientific inquiry and criminal trials would appear to share a noble mission. Both seek to reveal truth through rational examination of the available evidence.

However the vigorous debates of scientists engaged in the peer review of each other's work should not be confused with the adversarial features of a criminal trial.

Controversial scientific research and conclusions are customarily subjected to years of testing and challenge by many experts in the field.

Matters of fact in a criminal case are typically decided in the course of a few hearings, a trial and perhaps, an appeal. The expertise brought to bear will depend on what resources are available to the prosecution and defence and will typically be limited to the testimony of a handful of expert witnesses.

The area in which science intersects law is called forensic science, a strange territory indeed. It has given us major advances in the detection and investigation of crime, with DNA testing, fingerprinting and forensic phrenology just to name a few.

It has also given us several miscarriages of justice, such as the role of forensic hair matching in the wrongful execution of Colin Campbell Ross in 1922.

The bogus 'science' of hair matching is still being used to wrongly convict people, with William Gregory recently released after eight years in a Kentucky prison when hair matching evidence produced by forensic 'scientist' Dawn Katz was contradicted by the results of mitochondrial DNA analysis. Other forensic 'sciences' currently fighting for recognition in US courts include ear printing, brain printing, penile plethysmography and racial profiling.

Difficulties shared by lawyers, judges and juries in understanding complex scientific evidence have been well illustrated in some high profile cases. Few have been of higher profile than that of Lindy Chamberlain.

Telling in *Chamberlain* was that while the appeal judges were unanimous in overturning the original conviction, only Murphy seemed to appreciate the meaning of revelations that the test used to establish the presence of foetal blood in the Chamberlain Torana was not specific to human blood, or to blood at all. Although legal truth had been served and Lindy walked free, scientific truth had continued to elude the majority of the appeal panel.

Scientific evidence can be rendered unreliable by errors in principles, process, execution or interpretation. But an air of infallibility all too often precludes careful skeptical examination of scientific evidence in Australian courtrooms.

Over the past fifteen years the use of DNA profiling has put the spotlight onto the role of the forensic scientist with lawyers, politicians, media, biotech companies and the public taking an unprecedented interest in the use of science in the courtroom.

DNA profiling was originally developed as a method of determining paternity in which fresh samples taken under clinical conditions were examined for genetic evidence which could link parent to child. Within a very short period of time the same techniques were being used on degraded and mixed organic samples of often unknown composition collected under myriad different conditions to provide evidence used to send people to prison.

So rapid has been the introduction of the technology that it is often being 'tested' in court before it has been evaluated by the scientific community. Guidelines are developed only to be rendered irrelevant by innovations in theory and practice.

This paper does not purport to give definitive answers to questions about the scientific validity of the theories and practices employed in forensic DNA testing. It merely provides examples of how legal systems in Australia and overseas have attempted to meet the challenges they pose.

Alec Jeffreys and the birth of forensic DNA

In 1985, Leicester University geneticist Dr Alec Jeffreys was approached by West Midlands police who wanted to confirm the rape confession of a 17 year old boy and to try to link him to a second, related offence.

Jeffreys' work to date had focussed on refining DNA paternity testing techniques, which had already provided evidence in several UK palimony cases and at least one immigration case whereby a Ghanian boy was able to prove familial relationship with a UK citizen.

But for some years popular science journals had carried speculation that the DNA profiles obtained in this way might also be used in criminal identification. Jeffreys was to be the first to put these speculations to the test.

Comparison of the DNA profile of the boy with those extracted from samples taken from the victims eliminated him as a suspect. The result caused a sensation in the media as well as among investigators and the judiciary. The race to bring DNA testing into the criminal justice system had begun.

Within a year, Robert Melias in the UK had the dubious distinction of being the first person in history convicted on DNA evidence with Tommy Lee Andrews of Florida barely a month behind. Virginia was soon to execute Timothy Wilson Spencer following a prosecution case resting heavily upon DNA identification evidence.

'DNA fingerprinting', as its proponents liked to call it, had been blooded in court. But all was not smooth sailing for the new technology.

In 1989, Glen Woodall failed to convince a West Virginia jury that DNA evidence eliminated him as a suspect and he was convicted of the rape, kidnapping and robbery of two women, largely on the more 'conventional' forensic evidence of police serologist Fred Zain. That was not to be the end of the matter though.

Notwithstanding minor setbacks, DNA evidence gained rapid acceptance in US and UK courts, Australia joining in March 1989 with NSW vs Simpson.

So impressive was the new technology that many defence lawyers had already come to see it as unassailable. Almost 100 cases involving DNA evidence had gone to US courts by mid-1989 without a challenge to its admissibility.

But the methodology and techniques used in forensic DNA testing were beginning to come under scrutiny by the scientific community.

From 1987 popular science journals had been publishing articles critical of the lack of protocols regulating DNA testing and the interpretation of results it produced. One of the early critics was MIT's director of genetic research Dr Eric Lander, a man considered both brilliant and arrogant by friends and enemies alike.

These doubts were to reach the courtroom in August 1989, during the pre-trial *Frye* hearing of a murder case against New York handyman Jose Castro, the first time a serious attempt had been made to have DNA evidence excluded from a criminal trial.

The prosecution's expert witnesses were lead by Dr Richard Roberts, senior geneticist at Lifecodes and close associate of Nobel laureate James Watson.

The defence called Lander.

Castro - The new faith is tested

In February 1987 police found the bodies of the seven months pregnant Vilma Ponce and her two year old daughter Natasha in the Bronx apartment of Natasha's father, Jeffrey Otero. They had been stabbed, many times.

While questioning Jose Castro, the janitor of a nearby building who matched a witness description, a sharp-eyed detective spotted what may have been a bloodstain on his watch. He kept it for examination.

Soon Castro was under arrest and his watch, a sample of his blood and blood samples from the victims were on their way to Lifecodes laboratories for testing. Lifecodes reported that the DNA profile recovered from the watch stain matched that of Vilma Ponce and that there was less than one chance in 100 million that the profile of a randomly selected Hispanic-American would also match.

Events at the 15 week hearing into the admissibility of DNA evidence against Castro have been described by some commentators as the 'dissection' by Lander of the evidence presented by Lifecodes, but 'demolition' more accurately describes what transpired.

Lifecodes' reports had not hinted at any problems or irregularities in the testing, leaving it to Lander to uncover them with expert questioning. Uncover them he did, at one stage eliciting three contradictory responses from prosecution witnesses as they struggled to explain the lack of male DNA standards in determining the gender of the profile taken from the watch stain.

In the course of the hearing it emerged that

- no tests specific to human blood had been carried out on the stain (echoes of *Chamberlain*)
- tests on the stain had produced extra bands which had not been reported by Lifecodes
- tests on Natasha's blood also showed extra unreported bands
- the laboratory reused contaminated probes and failed to record such contamination

- Lifecodes had violated its own guidelines in declaring matches between bands which differed by over three standard deviations
- blind testing protocols had been ignored in the attempt to link the stain to the victims
- the lab had either failed to use control samples or failed to record their source

By the end of the hearing, two of the three scientists appearing for the prosecution had defected, joining with Lander in declaring that the tests conducted by Lifecodes were not capable of showing a link between the stain on the watch and Vilma Ponce. Judge Sheindlin threw the DNA evidence out of his court.

Shortly afterwards Jose Castro confessed to the murders of Vilma and Natasha Ponce.

In spite of the ironic outcome of the Castro case and efforts by elements of the forensic science and law enforcement communities to play down the significance of what it revealed about standards in forensic laboratories, defence lawyers took heart and a series of challenges to DNA evidence based on doubt about laboratory practices ensued.

The Castro hearing and subsequent similar challenges (such as Minnesota vs Schwartz) not only served to highlight the lack of standards and protocols in the rapidly expanding new science, they exposed some of the shortcomings in the older standards of admissibility for forensic evidence such as *Frye*.

Skepticism of forensic science was only to increase as more revelations about laboratory practices came to light. Ironically, the next blow against the reputation of forensic scientists was to be dealt by DNA testing itself.

Inherited evidence - policing and partial profiles

Police were quick to leap on the potential of DNA evidence in criminal investigation and equally quick to complain about the lack of clear authority they had to collect it.

Many relied on traditional methods for gathering such evidence, with one NSW policeman recently convicted of assaulting a motorist in order to gain 'consent' to a forensic procedure. But others, including some Victorian police, developed innovative strategies for obtaining the new clues.

The 'Operation Shadow' taskforce had been investigating a series of at least 14 rapes dating back to 1982 and had strong suspicions about the involvement of George Kaufmann. However legislation at the time did not allow the police to compel a sample and Mr Kaufmann steadfastly refused to oblige them with one.

Police had conducted numerous searches on Kaufmann's home, seizing used chewing gum, unwashed underwear, bedsheets and the knickers of Mr Kaufmann's girlfriend. All to no avail - the much sought after profile continued to elude their grasp.

Their luck changed after they tracked down the suspect's estranged wife and child, who were happy to volunteer samples. Subtraction of the maternal DNA from that of Kaufmann's child produced a partial profile of the father, which was then matched to samples taken from rape victims.

Kaufmann was arrested and immediately confessed to most of the rapes, although not those of the particularly old or young ("What do you think I am - an animal?"). He later volunteered a sample and pleaded guilty to all counts.

In 1988 a Victorian woman was brutally raped and strangled, her 18 month old daughter left with the corpse for hours before the crime was discovered. In an inspired piece of detective work for which Australian police are renowned, six of the 'usual suspects' were rounded up and DNA tested. Now the Homicide Squad had only to sit back and wait for the laboratory to tell them who done it.

Disappointed but not deterred at results showing that none of the initial suspects was their man, police went and rounded up three more, one of whom had been close to the victim at the time of her daughter's conception and refused to provide a sample.

The child was duly tested and results indicated that her father was the likely source of semen taken from her dead mother. The ex-boyfriend was told that he could clear himself of suspicion of murder if he submitted a sample, but still refused.

Shortly afterwards police were called to a fight at an office Christmas party between the suspect and his boss. Officers seized the bloodstained shirts of both fighters and the boss volunteered a sample. Tests indicated that the blood on both shirts was his.

Adaptation to DNA technology has not been limited to law enforcers however.

In the US and Australia prisoners have tried to foil DNA testing by rinsing their mouths with someone else's blood or saliva before submitting to a swab. One US prisoner who had been convicted of rape on DNA evidence even sent a sample of his semen to a female friend along with a request that she use it to register a rape case that would produce a DNA profile matching his own.

In October 1992, Dr John Schneeberger of Kipling in Saskatchewan raped a female patient while she was under sedation. The patient realised what had happened and registered a case.

Schneeberger submitted to DNA testing on at least three occasions. Each time the results showed no match between Schneeberger's blood and semen recovered from the victim.

In 1997 Royal Canadian Mounted Police took a sample of Schneeberger's hair, using a warrant obtained with evidence provided by a private investigator employed by the victim. This time a match was declared and Schneeberger was arrested.

It soon emerged that Schneeberger had surgically implanted a Penrose drain into his own arm, filling it with a mixture of anticoagulants and blood taken from a male patient. The drain was just under his skin at the point where blood samples are normally taken and had not been noticed by any of the police or medical personnel who had tested him previously.

Exoneration and exposure - DNA testing highlights forensic malpractice

Perhaps the first person to have his conviction overturned on DNA evidence was Gary Dotson who had been imprisoned since 1979 for rape, where he remained in spite of the alleged victim subsequently retracting her testimony. The governor of Illinois had refused to believe the retraction, perhaps because of evidence from a forensic serologist that Dotson, as a rare type B secretor, was far more likely to have left the stain on the victim's underpants than a randomly selected American male.

In 1988 Dotson's new attorney sent samples to Alec Jeffreys and a California lab for DNA analysis which positively excluded Dotson as the source of the crime stain. During the subsequent appeal it was revealed that the victim too was a type B secretor, a fact the prosecution serologist had kept from the original trial. Dotson was freed on August 14 1989 when the state attorney declined to contest his retrial.

Illinois was later to become the first US state to suspend its death penalty following a string of cases in which DNA testing had exposed malpractice and incompetence in the preparation of prosecution evidence, often by forensic scientists.

From a West Virginian prison, Glen Woodall was continuing his attempts to have DNA evidence exonerating him of the kidnapping and rape of two women accepted. His big problem was that the most experienced forensic serologist in the state, Fred Zain, had given evidence that Woodall's ABO, PGM, GLO and secretor types matched those found in semen samples recovered from the victims - making it extremely unlikely that someone other than Woodall was the perpetrator.

Improved testing and a new skepticism among the judiciary toward prosecution forensic evidence finally gained Woodall his freedom in 1993 and triggered an investigation of the State Police Crime Laboratories by the West Virginia Supreme Court.

Even the least expert of the investigators could see that Zain's reports to the court and sworn testimony in numerous trials were contradicted by his laboratory records and case notes, although this had never been picked up by defence attorneys.

The American Society of Crime Laboratory Directors was commissioned to review Zain's work. They found his misconduct was "the result of systematic practice rather than an occasional inadvertent error" and included

- overstating the strength of results;
- overstating the frequency of genetic matches on individual pieces of evidence;
- misreporting the frequency of genetic matches on multiple pieces of evidence;
- reporting that multiple items had been tested, when only a single item had been tested;
- reporting inconclusive results as conclusive;
- repeatedly altering laboratory records;
- grouping results to create the erroneous impression that genetic markers had been obtained from all samples tested;
- failing to report conflicting results;
- failing to conduct or to report conducting additional testing to resolve conflicting results;
- implying a match with a suspect when testing supported only a match with the victim; and
- reporting scientifically impossible or improbable results.

The court found that over 130 convictions resting on evidence from the police laboratories were unsafe. Fred Zain, by then head serologist in a Texas Medical Examiners office, was indicted for perjury.

Cases like these led US Attorney General Janet Reno to hail DNA testing as an invaluable tool in uncovering miscarriages of justice and announce a National Commission on the Future of DNA Evidence.

In September 1999 the Commission produced "Postconviction DNA testing: Recommendations for Handling Requests". Other than that it has mainly concerned itself with gaining acceptance for DNA evidence in courts and dealing with the huge backlog of untested samples amassed due to the boundless enthusiasm among US law enforcers and judiciary for the new technology.

But an investigation into the FBI's DNA Analysis Unit was to show that DNA testing was not the solution to the problem of incompetent and unscrupulous forensic scientists.

In 1995, FBI scientist Frederic Whitehurst blew the whistle on practices in the FBI's main forensic laboratories, which were then in the process of gaining independent accreditation

for their DNA testing program. Although most of Whitehurst's allegations centred on the distortion of evidence in explosives cases the US Department of Justice Inspector General launched a broad investigation into work done at the laboratories.

Documents obtained from the DOJ in November 1997 by the National Association of Criminal Defense Lawyers (NACDL) revealed a 'shoot from the hip' prosecution-friendly culture in the labs, in which

- lab technicians were pressured into claiming 'scientific certainty of a match' under oath - although such claims are not supportable
- all but one of the technicians in a DNA/serology lab had flunked an open proficiency exam, but the results had been destroyed and the test readministered, with all passing
- autoradiographs were frequently overexposed to make it easier to declare matches where none existed
- one technician had routinely manipulated results of tests he believed to have come from Afro-Americans in an attempt to indicate that the suspect was guilty
- plastic pipettes were used to extract DNA dissolved in chloroform - although chloroform also dissolves plastic pipettes, thus contaminating the sample
- quantities of DNA placed in the testing gel were not measured - although excess quantities were known to result in false readings
- FBI protocols for adjusting readings to compensate for possible 'bandshift' permitted margins four times those recommended in the scientific literature
- internal criticism of forensic techniques was suppressed and dissenters isolated

The report eventually produced by the Inspector General contained nothing which might identify unsafe convictions arising from tainted DNA evidence from FBI labs. At the time of writing the NACDL was still trying to get 90% of the material examined by the inquiry released under Freedom of Information laws.

Errors at ESR

Even New Zealand was soon caught up in the enthusiasm for forensic DNA testing, although it was initially ill equipped to carry it out. Nonetheless the Criminal Investigations (Blood Samples) Act was quickly passed in 1995 "in order that a DNA databank can be created for the investigation of criminal offences", according to Environmental Science & Research Ltd (ESR), the main proponent and beneficiary of the legislation.

As has been the case in many other jurisdictions, enthusiasm for the new technology exceeded expertise and ESR's Mt Albert laboratories soon found themselves at the centre of two high profile cases which serve as textbook examples of what can go wrong in DNA

testing laboratories, even those which are fully accredited and meet internationally accepted quality control guidelines.

In 1996, Peter Robert Howse was arrested for the rape of a teenager on the basis of strong evidence which included identification by a witness. Samples taken from Howse and the victim were sent to ESR labs for SLP (RFLP) testing. ESR reported no match, apparently eliminating Howse as a suspect, and he was released.

In 1999 Howse was arrested and tested again in connection with at least three further rapes. In the meantime ESR had switched to STR (PCR) testing. The results strongly implicated Howse in the 1996 rape as well as those being investigated.

The inquiry ordered by the NZ Department of Justice found that ESR had failed to gain a result with the 1996 tests, but laboratory policy had led to 'no result' being reported as 'no match'.

ESR conceded that 'with hindsight' it might have been better if failure to get a result was reported as such, but explained that they adopted a 'conservative' approach to reporting in order to give the accused benefit of any doubt.

Meanwhile the collection of DNA samples for the ESR database continued apace.

One caught up in the testing was a mild mannered Christchurch man who had been assaulted outside his local, the Hagley Arms Hotel, on 23 April 1998. Police had taken blood in order to eliminate his DNA from samples taken from the scene of the assault and sent it to ESR for testing. The result of this test came to be dubbed 'Profile N' by the inquiries which were to follow.

Wellington police were then investigating two murders.

Operation 'Pad' had collected evidence from the February 21 murder of Bill Fleet in his home. There were witnesses to the event and a man had been arrested and charged. Blood stains on a roller door at the murder scene were sampled and sent to ESR for analysis.

Operation 'Rex' concerned an 18 January murder on gang premises at Porirua. Some weeks later Mr Kuka Tiai was arrested and charged. He immediately confessed, saying he had acted alone. Samples were taken from the crime scene and the deceased and sent to ESR.

Samples from under the fingernails of the deceased and from spots on a wardrobe at the scene produced a profile which failed to match either Mr Tiai or his victim. Suspecting an accomplice, police requested that ESR conduct a search of its database for matching profiles.

ESR found two. One was from a rollerdoor sample taken in 'Pad' and the other was Profile N, which ESR claimed was likely to occur in only one New Zealander in 930 million.

The Christchurch assault victim was subjected to 'extensive police inquiries' for more than three months and his financial records were seized. This established what he had claimed all along, that he had not left Christchurch around the time of the murders. In fact he hardly left Christchurch at all.

In the Sharman inquiry which followed, ESR suggested that the assault victim may have a brother who had been at the crime scenes and that this would have greatly increased the chances of gaining a matching profile. When it was pointed out that he had no brothers ESR countered with the possibility of an unknown half-brother. After all none of us can really know what our parents have been up to. Sharman seemed to accept that this was a possibility but the later Eichelbaum-Scott inquiry was less charitable.

Sir Thomas Eichelbaum and Professor John Scott, assisted by an impressive array of legal, forensic and scientific experts, conducted a thorough investigation into the collection, transport, storage, testing and analysis of the samples in question, reporting in November 1999.

Although they never discovered exactly how the mistakes had happened they did determine that the 'Rex' and 'Pad' samples had been accidentally contaminated with DNA from Profile N at an early stage of processing at ESR's Mt Albert laboratories. Extracts from them sent to other laboratories for testing also returned Profile N.

Numerous recommendations for improving oversight, record keeping and even ventilation at the laboratories were made. Strangely, no recommendations were made about ESR's methods of calculating match odds, although renowned expatriate New Zealand population geneticist Dr Bruce Weir had declined to endorse them.

During the inquiry ESR was asked to check the results of all testing done in July 1998 for any further instances of Profile N. Although they initially reported that none were found, later retests showed a partial profile consistent with N in another sample from 'Pad'. They also revealed 25 other 'unexplained' profiles in 14 of the 36 samples tested that month.

What do these cases say about DNA testing at ESR?

Justice Action asked Wayne Chisnall, ESR's 'General Manager Forensic', who assured us

In your question #8 you infer that ESR has had failures with DNA. This is not correct:

-The Howse case was all about the success of DNA. Old SLP technology did not

conclusively pick up DNA from the accused but the new STR multilocus system did. New technological advances are inevitably going to be more sensitive than their predecessors.

-The Wellington murders you refer to were not DNA failures. The problem was picked up and investigated. Five separate investigations failed to find scientific proof for the cause of the anomalies. No direct evidence of either accidental or deliberate contamination has come to light. Existing facilities and protocols were shown to meet independent quality audit requirements. The Ministerial Inquiry recognising the points above concluded that on the balance of probabilities the apparently anomalous results could be ascribed to accidental contamination of DNA extracts within the ESR laboratory. They made a number of recommendations which ESR has either implemented or is planning to implement. This sits comfortably with our continuous improvement management focus.

[Personal communication, 28 April 2000]

ESR senior scientist John Buckleton was more candid. In response to questions about statistical models used by ESR he replied in part

It is intrinsically impossible to estimate error in the model. We use the subpopulation model which is a summary of a very complex human evolutionary process. However we cannot empirically test our estimates with any real belief in the testing process. The closest we can get is our Tippett testing. This however, per se, is a very big question and cannot be answered simply.

And to a question about the estimated error rate in the lab;

ESR reports the probability of a match by chance (in fact we report the LR).

The "match by error" is a separate source of error and is not part of the population genetic argument. The argument that it may be the larger of the two gains credibility as the "match by chance" gets smaller.

ESR accepts that both avenues are legitimate sources of cross examination.

We are at this time unable to quote an estimate of the potential for "match by error" for any given case.

[Personal communication, 27 April 2000]

Perhaps, but given that the inquiry exposed four matches by error in less than two months of ESR testing, it will take several centuries of 'continuous improvement management focus' to reduce the overall error rate of the Mt Albert labs to anything like 1 in 930 million.

New Zealand's Justice Minister Phil Goff uses plainer language.

What worried me was that, okay, this was a very clear-cut case where the man couldn't have committed the crimes. Had he been a gang member and lived in Wellington ...

Cold hits vs hard facts

The way forward for those wishing to gain prosecutions with DNA evidence now seemed clear.

Large reference databases must be built up as soon as possible to avoid the questions of statistical validity which bedevilled the early days of DNA evidence (such as in *Green, Pantoja, Tran* and *Milat* in NSW). Earlier practices, like taking profiles from Red Cross blood banks without the knowledge or consent of donors, would cease to be sustainable as more people learn of how much personal information can be extracted from these samples. Prisoners can easily be exploited to meet this objective however, so they are.

More polymorphic alleles must be added to the range of loci tested so that the product rule can be used to generate match odds of jury-boggling proportions.

The theories of subpopulation variation in allele distribution which had been developed by population geneticists in response to known ethnic variations in the distribution of blood groups must be discredited to avoid complicating the already difficult explanations of match odds calculations.

Any attempt to quantify the possibility of laboratory error must be resisted to avoid providing statistical evidence which would undermine the astronomical match odds used in court.

Wherever possible the chance of a DNA match arising from a blood relative, or even an identical twin, must be ignored.

In meeting the objective of gathering large databases authorities in most jurisdiction have swamped DNA testing facilities with samples taken from prisoners. The resultant mass of data quickly suggested a new possibility for DNA prosecution - full database trawls in which the DNA of a huge number of individuals would be checked against that taken from crime scenes in an attempt to gain 'cold hits'; matches which might crack cases for which there isn't even a suspect.

However huge databases bring their own problems.

For instance, if a DNA test capable of distinguishing between 'unrelated' people with one million to one confidence was used to create a database of two million personal profiles from a population of 20 million potential suspects you could be pretty certain that most crime stain profiles run against it would produce at least one cold hit.

You could also be more than 90% certain that it would be the wrong cold hit. You could further expect that around 80% of the personal profiles on the database would match at least one other on record from a different person.

Problems like these had led the 1996 National Research Council publication "The Evaluation of Forensic Evidence" (NRC-II) to recommend that "When the suspect is found by a search of a DNA database, the random match probability should be multiplied by N, the number of persons in the database".

Director of the Virginia Division of Forensic Science and Chair of the Laboratory Funding Working Group of the National Commission on the Future of DNA Evidence, Dr Paul Ferrara, was quick to deal with the problems the NRC-II recommendation caused him, with his database of 150,000 prisoner and arrestee samples which he regularly trawls for hits. In his 1997 article "DNA databanking - the next step", he tells us

Taking a liberal interpretation of this [NRC-II] statement, the Virginia Division of Forensic Science has adopted the following policy on databank hits: When a search of the databank results in a single match, the report will simply state that the search of a databank of X number of profiles resulted in a match. When, based on this probable cause, a direct comparison is made, that final report will be reported using standard random-match probability calculations.

He concludes his essay optimistically

Finally, while I must be dreaming, let me include [the wish] that our DNA results will be accepted readily by the courts, recognizing that DNA testing is the most objective and reliable form of forensic analysis available today.

Dream on Dr Ferrara.

Dr John Buckleton told the Commission that there are at least 10 cases of different individuals sharing the same DNA profile recorded on ESR's database of 10,907 6-loci profiles. In two of these cases the people sharing profiles had no known family relationship.

This problem is not likely to afflict Dr Amanda Sozer of Fairfax Identity Labs. In her evidence to the Commission she says

when the samples [are] coming into the lab they look for duplicates. 2 percent get by. They have a different corrections number, they have a different name, they have a different Social Security Number, they have a different date of birth. So there are a large number of samples that go all the way through the testing process and it's not until they put them into their database that they realized they have duplicates.

Her solution is to assume that the identifying data is in error and record duplicates as a single individual.

By February 2001 UK police had amassed a database of over 1 million personal profiles along with almost 100,000 crime scene profiles. This database is constantly expanding and police report hundreds of matches every month, using 6-point testing which claims match odds of about 37 million to one. This is to be expected.

What is also to be expected from a thorough trawl of this mammoth database would be around 100 billion attempts to match crime scenes with potential suspects, resulting in over two thousand false cold hits. More if the labs are capable of making mistakes.

The first false cold hit from a database trawl to be recognised in the UK was in 1999, though it did not become public knowledge until the following year after a UK forensic scientist addressed the USDOJ Commission on the Future of DNA Evidence.

A man with advanced Parkinsons disease who could not drive an automobile or dress himself unaided was linked to a burglary which had occurred 200 miles from his home. In spite of protestations of innocence and alibi evidence police arrested him because the DNA profiles matched and 'so it had to be him'. It was several months before 10-point DNA tests were done on samples from the suspect and the crime scene. The results exonerated him.

He gained his freedom and a brief note from the prosecutor saying that charges were being dropped because "there was not enough evidence to provide a realistic chance of conviction". He still awaits an official apology. Or even an admission of error.

In 1996 five different commercial premises in Birmingham were robbed. Police noted several similarities between the robberies including the manner of entry to the premises, the sophistication of the safe-cracking methods employed and the lack of fingerprints left behind. Oddly, the police recovered several cigarette butts from the crime scenes which they theorise were dropped by an offender who smoked while the safes were being opened. The use of forensic DNA in such cases had received prominent coverage in the British media for several years prior to the robberies.

In December 1998 Mr Robert Watters, who lived near the scene of the robberies, was arrested in relation to unconnected offences and DNA tested. Although the judge in this

case instructed the jury to acquit, the profile obtained from his sample was run against the UK database and matched with DNA which had been recovered from the cigarette butts. Mr Watters was arrested, charged and convicted.

During the trial FSS scientist Valerie Tomlinson told the court that the probability of a false match between Watters and the butts was 1 in 86 million. Under cross examination she conceded that there was one chance in 267 that the DNA on the cigarette butts could have come from one of Watters' two brothers.

The prosecution led no other evidence which tended to exclude the defendant's brothers as contributors of the DNA, in fact one of them had previously been questioned by the police in relation to the robberies. The case against Watters consisted of the DNA match, that Watters had bought cigarettes (i.e. he may be a smoker), his proximity to the scenes of the robberies and the fact that like most safe crackers, Watters is male. The trial judge also seems to have drawn inference from the fact that Watters had declined to provide the police with his brothers' home addresses, although he instructed the jury against engaging in such 'dangerous speculations'.

Watters' conviction was quashed in October 2000 when an appeal panel found that the prosecution evidence did not constitute a prima facie case which could be safely left to a jury. During the appeal, reference was made to another UK case in which a man who had been linked to an offence by database trawl was acquitted when it was discovered that someone with an identical DNA profile lived closer to the crime scene than he.

Trawling the massive UK database in the attempt to link unsuspected (and often unsuspecting) people to unsolved crimes raises many questions about mass DNA testing and databasing.

Perhaps the most pertinent is: What has happened to the subjects of the many hundreds of false cold hits which UK authorities have as yet failed to recognise?

Should we trust Profiler Plus?

While increasing the number of alleles tested can (theoretically) reduce the number of chance matches thrown up during database trawls, this solution too brings problems of its own.

Testing loci one at a time is not only time consuming, evidence consuming and expensive, the likelihood of laboratory error increases for every extra locus you test. Lab kits which can test multiple loci at once have obvious potential advantages in cost and reliability.

But it is not as simple as mixing the restriction enzymes from several kits in a test tube and dropping in a sample. Different primers react optimally at different temperatures and

with different sized samples. Worse, different primers have a tendency to react with each other, generating false readings and obscuring real ones.

The biotech industry rose to the challenge and by 1994 several duplex (two-loci) and triplex (three-loci) test kits had been validated according to the guidelines of the US-Canadian Technical Working Group on DNA Analysis Methods (TWGDAM, since supplanted by the FBI's SWGDAM).

But the establishment that year of the FBI's CODIS database called for mass testing at 13 different genetic loci, making even triplex testing an unsatisfactory solution.

Along came Dr Bruce Budowle, with the promise of combining the FBI's DNA laboratory data and facilities with Perkin Elmer's research and marketing expertise to produce a kit which could reliably test *all* of the 13 loci used by the FBI in a single procedure. The FBI was enthusiastic, Perkin Elmer less so until Budowle threatened to go to their competitor Promega, and work soon began on what was to become the most widely used forensic DNA test kit in the world.

Although the ambitious project was beset with difficulties, several years and many millions of dollars later it produced two kits. The Profiler Plus could co-amplify 9 of the 13 loci used in CODIS, while its sister kit Cofiler could co-amplify 6 (the two loci overlap providing some assurance that the same DNA source is being amplified by each kit).

Understandably, Perkin Elmer is keen to see some profit from this huge investment. This would be unlikely to be realised if other companies, especially those not restricted by US patent laws, were able to manufacture cheap copies of its new kits.

A veil of 'commercial in confidence' descended over anything which might give PE's rivals hints, including the composition of the kits' primers and, strangely, the results of in-house verification testing which had been conducted by PE and the FBI.

Perkin Elmer claims that other validation studies have been done, and quotes the results allegedly obtained from them in the manual it supplies with the kits, but according to Judge Hale in "Colorado v Schreck"

PE's chapter on validation in its User's Manual is not a validation study in any meaningful sense. This study does not comply with TWGDAM's rigorous demands. It fails to include its developmental data or the results of its studies, and is more a brief summary than a validation study. Furthermore, PE has resisted releasing its developmental data claiming that the data was unavailable, that it had never been systematically recorded, that it was scattered throughout various departments at the company and its collection at this time would be unduly burdensome.

This makes it all but impossible for the independent scientific community to conduct proper peer evaluation of the effectiveness and reliability of Profiler Plus and puts the kit in breach of TWGDAM and NRC standards.

Nonetheless a worldwide public relations push soon saw Profiler Plus in use in hundreds of labs around the globe, including every forensic DNA testing laboratory in Australia. However, as Judge Hale also noted "*reliability is not shown simply by aggressive marketing*".

So what can be said about the reliability of Profiler Plus?

Multiplexor STR profiling has its problems, including stutter, variable peak height ratio thresholds, allelic drop-out and pull up. But within the relatively short period the new Perkin Elmer kits have been in use extra problems have been noted which are specific to each kit.

In testing 6 loci on an unmixed, undegraded sample Cofiler can be expected to return 6 bands indicating the position of each allele amplified. Problem is that in a high (but unmeasured) proportion of tests Cofiler returns 7 bands. Perkin Elmer mentions this glitch in its manual but fails to offer an explanation for it.

In early 2000, ReliaGene Technologies in Louisiana analysed the results of thousands of tests done with the Profiler Plus test kit. Readings were compared with those given by a Promega's TWGDAM compliant GenePrint Sex Identification System-Amelogenin kit which amplifies the sex markers using different primers to those in Profiler Plus.

Checking the results of tests on 7,220 male samples, ReliaGene found three instances in which Profiler Plus had failed to amplify the x-chromosome specific amelogenin marker where other kits had successfully done so. An error rate of about 0.04% may not seem much, but it is considerably greater than is reflected in match odds calculated using Profiler Plus test results and is likely to add significantly to the problems which emerge with the use of large databases.

Analysis of the results produced by Profiler Plus have become largely automated, with the ABI Prism 310 & 377 Genetic Analysers running Genotyper 'expert system' software the tools of choice. Much of the signal filtering and allele labelling done by Genotyper software has been developed using assumptions based on the validation studies allegedly done by PE and the FBI, but not available for peer review. At least one of these assumptions seems to be of peak thresholds for stutter which are sometimes exceeded in actual casework. This can potentially result in 'ghost profiles' of primary samples which appear to show mixed profiles where none exists or even an incorrect unmixed profile if the 'expert system' filters out the wrong peak.

Doubts about Profiler Plus and other Perkin Elmer kits has led to the exclusion of DNA evidence in several US cases to date under admissibility standards such as *Daubert*, *Kelly* and *Streich* which have come to supplant *Frye* in various US jurisdictions. Cases like *Colorado vs Schreck*, *California vs Bokin* and *Vermont vs Pfenning* have been emulated in Australia, with *NSW vs Sotheren* and *NSW vs Gallagher* declining to endorse the reliability of Profiler Plus pending further information from PE.

However in an earlier NSW decision Jason Lee Rees was not so lucky.

In November 1998 police had searched Rees' house in connection with the killing of David Palin, seizing a pair of Nike running shoes. Samples lifted from the shoes were sent to the Division of Analytical Laboratories which found too little DNA to be analysed with the methods they then used.

But the advent of Profiler Plus testing meant that smaller samples could be analysed than previously. So in February 2000 DAL's senior forensic biologist, Robert Goetz, retested the sample and obtained a match between a stain on the joggers and DNA from the deceased. Rees was arrested and charged.

During the admissibility hearing defence pointed out that the size of the DNA sample tested was less than one third the minimum recommended in the Profiler Plus users manual. Astonishingly Goetz countered with evidence indicating that no forensic laboratories currently using Profiler Plus follow the manual, suggesting that there existed widespread acceptability among forensic scientists towards ignoring the official PE guidelines to a complex technical procedure which noone outside of Perkin Elmer really understands. Even more astonishing was that Justice Bell seemed to accept this line of reasoning.

The DNA evidence was admitted and Rees convicted of manslaughter. Although Rees was soon to be released on appeal, Bell's reasoning on the DNA evidence was never brought into question.

In *California vs Bokin* evidence produced by the ABD Green One was also deemed inadmissible following Perkin Elmer's reluctance to provide developmental data about the kit. During the hearing Judge Sanders made the following observations of prosecution forensic scientist Alan Keel.

During the discovery process Keel submitted a lengthy declaration challenging the defense motion. It was beyond advocacy - it indicated a critical attitude toward the defense function in a criminal justice case.

While on the stand, Keel regularly indicated he chose to disregard particular protocols suggested in the literature, including that of Perkin-Elmer and peer reviewed journals.

Any relevant documentation on this topic and certainly the case law which controls the admissibility of Keel's work product mandates that DNA analysis is technical and rigorous analysis.

It is not something that should be rushed because the technician has a heavy case load. It certainly should not be something so basal that it could be performed in a barn [as Keel had suggested while under oath].

Unlike Promega, Perkin Elmer continues to refuse to release its primer sequences for peer review. PE has said that it will reveal all to defence teams under strict non-disclosure terms but it is far from clear how this will assist qualified independent scientists wishing to carry out the kind of examination necessary to properly evaluate PE kits.

Nonetheless, huge investments in cash and reputation are at stake and US and Australian courts have begun looking more favourably upon prosecution claims for the reliability of Perkin Elmer's products, with almost a dozen hearings admitting Profiler Plus and ABI 310/377 evidence by May 2001.

In March 2001 the South Australian Supreme Court deemed Profiler Plus evidence admissible in *R v Karger*.

Justice Mullighan seemed unconcerned at Perkin Elmer's reluctance to release primer sequences or full validation data and essentially reduced the question of reliability to a credibility contest between prosecution and defence expert witnesses. Mullighan found not only that the claims made by the defence experts were without substance, but that they constituted serious but baseless allegations against the prosecution expert Chris Pearman.

The learned judge made much of the alleged expertise of practicing forensic scientists in distinguishing between artifacts of the testing process and true readings, apparently unconcerned or oblivious to the fact that Genotyper software has taken many of these judgements out of the hands, and sight, of the technician analysing results.

In the course of the hearing he accepted evidence from Pearman that the mutation rate at binding sites used by Profiler Plus primers was between 0.01 and 0.001%. This evidence was supported by reports provided to the court of US studies carried out by Perkin Elmer and Bruce Budowle. Actually the studies showed a single dropout at the *vWA* locus in 600 tests, which combined with the 3 dropouts in 7,220 tests at the x-specific amelogenin locus documented in October 2000 (*Schewale et al*) would indicate a known error rate due to dropout of around 0.2% for Profiler Plus DNA testing.

Apparently the court was not made aware of independent studies published in October 2000 which indicate a mutation rate at one binding site exceeding 0.04% (*Schewale et al*).

Mullighan was extremely critical of defence expert Dr Davis for turning off the stutter filter during her analysis of the sample, dismissing her contention that this is a necessary precaution when undertaking criminal casework. Noone asked Pearman if modifications to the Genotyper 'Kazam' macro had been carried out, recommended in July 2000 by Kinsey and Hormann as a necessary measure to reduce a source of error they dubbed 'stutter-filter backtalk'. Failing implementation of this patch, and fixes for any other bugs which may still lurk in Genotyper software, the most responsible course to follow in analysing criminal casework would be to turn the stutter filter off.

Davis provided a lot of evidence which would have been useful in assessing the reliability of the tests, but there can be no denying that she presented badly in court and it was almost entirely rejected. Much was made of her evidence in previous US trials in an attempt to show that she was inconsistent and partisan in her deployment of the facts. While there was justification for this, one wonders what might have been concluded had a similar exercise been carried out upon the prosecution's experts.

In rebutting Davis' claim that "*it is not going to be an uncommon or non-existent event to find two people whose profiles match at all loci inspected by Profiler Plus*", Dr John Buckleton of ESR told the court that only one such case had been found, in a remote South American tribe. He did not see fit to repeat evidence he had recently given in the US that ESR's pre-Profiler six-point database contains several instances of duplicate profiles. Mullighan found that "*for practical purposes it is generally regarded that such a match could not occur*".

Mullighan also rejected the defence evidence of Dr Atchison that it is necessary to apply estimates of laboratory error rates to the match likelihood ratio before odds of a random match can be properly put to a jury. In spite of his experiences at ESR and his recent work in correcting errors on South Australia's FSC database, Dr Buckleton assured Justice Mullighan that such errors should not be taken into account.

On April 23, 2001 the Colorado prosecutor's office mounted an appeal against the decision to exclude Profiler Plus evidence in Colorado v Scheck. Apparently an appeal was considered more appropriate than a retest using a peer validated kit. The case was heard by Justice Rice, who has a solid track record of admitting DNA evidence.

Rice leaned heavily upon his own previous judgements in justifying his rejection of the *Daubert* and *Frye* criteria of admissability used in the original hearing. Instead he relied on a Colorado standard called CRE 702 which does not require acceptance by the scientific community of a particular technique or theory before it is accepted in court, going instead to the issue of the qualification of the expert witnesses advocating it. In the US too, scientific fact was now to be determined according the credibility of witnesses claiming it. The original trial court was overruled and the Profiler Plus evidence accepted.

The implementation of Profiler Plus, the ABI Prism 310/377 Analysers and Genotyper software has taken much of the responsibility for reliable forensic testing out of the hands of technicians, burying it in proprietary software, secret primers and unpublished developmental data. It has also made it far more difficult for defence to discover information which could be used to assess the reliability of the test in question. Forensic labs no longer seem to feel the need to account for *any* possibility of error when presenting evidence. Indeed, Perkin Elmer's corporate secrecy makes it difficult for technicians to know what errors may occur. Whether an Australian lab using Profiler Plus and ABI 310/377 can reasonably claim to have confirmed a test result by sending it to another lab using Profiler Plus and ABI 310/377 for verification seems doubtful.

Courts have responded to the extremely technical nature of the arguments and the lack of independent data by weighing the experience and credibility of expert witnesses instead of the scientific validity of their evidence. Naturally forensic scientists employed in state funded crime labs have a near monopoly on experience with the new and expensive tools, especially in Australia.

Perkin Elmer has now established new and more liberal guidelines regulating the admission of scientific evidence through the simple expedient of ignoring the existing ones and employing a bit of marketing muscle. The rise of DNA testing has often been compared with the parallel rise of home computing. Perkin Elmer is on track to become the Microsoft of the forensic testing industry, making the Profiler/ABI/Genotyper combination into the equivalent of the ubiquitous Pentium boxes running Windows.

The scientific jury is still out on Profiler Plus, and will remain so until PE releases the information needed to independently validate it. The courts, it seems, have more faith in the biotech giant.

Conclusion

The race to introduce large scale DNA profiling into criminal justice systems worldwide has led to rapid changes in the methods and technology employed in forensic laboratories and explosive growth in the forensic testing industry.

While law enforcement agencies have adapted quickly to these changes the courts have struggled to keep up with challenges posed by the new technology. Further behind are the academic and scientific community, who are yet to properly assess many of the theories and techniques which have become commonplace in our courtrooms.

Last of all come standards and protocols.

Traditional methods of setting legal and scientific standards have failed to deal with the pace of technological change. By the time a protocol has been widely agreed upon it is already being rendered irrelevant or impractical by changes in technology or the requirements of DNA testing stakeholders.

The first 15 years of DNA in the courtroom have been characterised by long periods of legal incomprehension and impotence punctuated by occasional skepticism, even cynicism, following a well resourced and well prepared challenge.

While this pattern persists those able to bring to bear high quality expert testimony will continue to slug out the validity of each innovation, while poorly resourced defendants remain fodder to the big guns of the biotech industry.

According to Karl Popper, the test of a scientific theory is its falsifiability.

He didn't mean that it must be easy to falsify experimental results or to draw false conclusions from them, rather that it must be possible to obtain evidence which can potentially disprove a theory before it can be considered scientific. It is questionable whether this prerequisite can be met in a courtroom in which none are really able to comprehend, much less challenge, the 'scientific theory' suggesting guilt.

Widespread enthusiasm for continued 'advances' in forensic DNA technology among law enforcers, politicians, the media and sections of the legal profession has provided little basis for its well considered introduction. While it might be hoped that recent investments in Australian labs and databases will give the medium term procedural stability needed for the development of reliable and widely accepted standards, the experience in the UK and US can give little ground for confidence.

In his 1991 essay "Miscarriages of Justice in Serious Criminal Cases in Australia", Paul Wilson lists 9 Australian cases in which the conviction was later quashed or set aside. In five of them the original unsafe conviction was obtained using inconclusive or partisan expert evidence. Wilson notes that "*key forensic witnesses take on the role of propagandists for the prosecution, rather than the role of being impartial interpreters of scientific evidence*".

The culture of forensic science is not one of disinterested weighing of evidence in the search for objective truth. Forensic 'scientists' such as Roberts, Zain, Ferrara and Keel have instead embraced the culture of the courtroom, selectively presenting evidence in a partisan light in an attempt to establish a predetermined conclusion. This is the antithesis of true science.

Forensic scientists who retain a personal commitment to objective truth find themselves caught between spiralling workloads, frequent changes in practices mandated by

technology or regulation and pressure from authorities and corporations who have justified huge investments with unrealistic predictions of clear up and conviction rates. That scientific objectivity, technical expertise and appropriate care and attention be maintained under such conditions is a lot to expect, but vital if forensic DNA testing is not to lead to further miscarriages of justice.

If one and a half centuries of forensic science and a decade and a half of DNA profiling have taught us anything it is that the adversarial courtroom is no place for the determination of scientific truth.

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Glossary

Allele One of two or more alternative forms of a gene. In DNA identification, the definition is extended to any DNA region used for analysis.

Allelic drop out Failure to detect an allele within a sample or failure to amplify an allele during PCR.

Amelogenin A system that generates different values for the X and Y chromosomes. Used for sex identification.

Amplification Producing multiple copies of a chosen DNA region, usually by PCR.

Bandshift The phenomena whereby different distances matching RFLP fragments move through agarose gel during different electrophoreses can result in false readings. Usually attributed to variations in the composition of the gel or the skill of technicians performing electrophoresis.

Confidence interval, confidence limit A numeric range, based on a sample, that is expected to include the population mean value a specified proportion of the time (e.g., 95 percent).

Electrophoresis The technique of separating different sized DNA fragments by placing them in a gel and subjecting it to a strong electromagnetic field. Smaller fragments will generally migrate further through the gel in a given time than larger ones.

Gene The basic unit of heredity; a functional sequence of DNA in a chromosome.

Locus (pl. loci) The physical location of a gene (or DNA region of interest) on a chromosome.

Likelihood ratio (LR) the ratio of two probabilities of the same event under different hypotheses. In DNA testing often expressed as the ratio between the likelihood that a given profile came from a particular individual and the likelihood that it came from a random unrelated person. Note that in this case the likelihood of each event does not add to give 1 (100% likelihood) as it does not incorporate the possibility of error or that the profiles came from twins or other near relatives. To turn a likelihood ratio into a meaningful measure of the chance of a false match it must be applied to posterior odds using Bayes theorem. The posterior odds should incorporate any possibilities not accounted for by the two hypotheses. Examples of these would be that the sample came from a relative, that more than one profile had been checked in order to gain the match, that a mistake had been made in the lab or that the testing kit used was less than 100% reliable. Care should be taken to ensure that elements used in determining posterior odds do not overlap with other trial evidence or there is the risk that they will be weighed twice by the court.

Marker An easily detected gene or chromosome region used for identification.

Match by chance When DNA profiles obtained from different sources are found to match due to inherent limits in the discrimination of the testing method used. Also *random match* or *adventitious cold hit*.

Match by error When DNA profiles obtained from different sources are found to match because of mistakes made during collection, transport, storage, testing or analysis.

Multiplex A system for analyzing several loci at once.

Off ladder A STR result known to be in error because it shows a number of repeats which is not present in the human population (i.e. is not found on the 'ladder' of known human alleles for that locus).

Polymerase chain reaction (PCR) An in vitro process for making many copies of a chosen fragment of DNA.

Polymorphism The presence of more than one allele at a locus in a population; usually the word is used only when at least two alleles are fairly common.

Primer Enzymes used to isolate a particular marker on a DNA molecule for amplification or detection. Primers rely on the presence of non-polymorphic sequences in close proximity to the polymorphic locus of interest. The occasional drop out of the x-specific amelogenin marker during Profiler Plus analysis is probably due to mutations at the locus used as a binding site by one of Perkin Elmer's secret primers.

Primer dimers False readings produced during multiplex testing when primers bind to each other instead of to binding sites on the target DNA.

Pull up When attempting automated laser fluorescence analysis of multiplex results some alleles will produce stronger readings than others. Strong laser signals are often scattered to inappropriate detectors, resulting in 'noise' which must be filtered out during analysis. If detectors are set with sufficient sensitivity to register faint results there exists the possibility that stronger signals will saturate a detector and produce an 'off-scale' reading, making true signal peak determination impossible. This can interfere with software macros designed to separate signal from noise, producing artifacts such as false 'bleed-through' peaks.

Random-match probability The probability that the DNA in a random sample from the population has the same profile as the DNA in the evidence sample. The probability of a match by chance.

Restriction enzyme, restriction endonuclease An enzyme that cuts a DNA molecule at a specified short base sequence. Commonly used as primers in RFLP analysis.

Restricted fragment length polymorphism (RFLP) Variation in the length of a stretch of DNA. Alternately, a method of analysing DNA which relies on these variations to distinguish between sample sources.

Short tandem repeat (STR) Repeated DNA sequences in which the repeat units are typically three, four, or five base pairs. Alternately, a method of analysing DNA based on variations in the number of these repeat units.

Single locus profiling (SLP) Analysing DNA one locus at a time. Commonly used in RFLP testing as well as early PCR tests.

Stutter An artifact of PCR STR amplification which can cause false readings. Thought to be caused by 'slippage' of the polymerase along a STR sequence during amplification, resulting in amplification of only a subset of the tandem repeats being examined. The

earlier slippage occurs during amplification the more difficult it is to determine the true number of repeats, unless the stutter produces an off ladder result.

Variable number tandem repeats (VNTR) Repeating units of a DNA sequence; a class of RFLPs.

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Appendix

US standards for admissibility of scientific evidence

The *Frye* standard for admissability of scientific evidence was set in 1923 (*Frye v. United States*, 54 App. D.C. 46, 293 F. 1013, 1014). Although it has largely been supplanted in recent decades it is still regularly applied in US hearings in which scientific evidence is said to be novel or new.

Under *Frye*, those wishing to introduce scientific evidence must satisfy the court of

- 1) general acceptance in the relevant scientific community of the underlying theory or principle; and
- 2) general acceptance in the relevant scientific community of techniques used to apply that theory or principle

In *Castro*, Judge Scheindlin found that in determining whether DNA evidence complies with *Frye* the court must consider whether

- 1) there is a theory, which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results;
- 2) there are techniques or experiments that currently exist that are capable of producing reliable results in DNA identification and which are generally accepted in the scientific community; and
- 3) the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case.

Following *Castro* many US states introduced their own standards of admissibility which either supplemented or supplanted *Frye*. In 1993 the US Supreme Court case *Daubert v. Merrell Dow Pharmaceuticals, Inc* (509 US, 579) set the standard for scientific evidence which provides the current model for many other US jurisdictions. Under *Daubert* the court must consider

- 1) The testability of the scientific theory or technique;
- 2) Whether the theory or technique has been subjected to peer review and publication;
- 3) The known or potential rate of error;
- 4) The existence or nonexistence of maintained standards; and
- 5) Whether the theory or technique has general acceptance in a relevant scientific community.

In overturning the original ruling in *Colorado v Schreck*, Justice Rice rejected the use of *Daubert* by the trial judge, invoking instead Colorado's CRE 702 which requires the court to consider

- (1) the reliability of the scientific principles;
- (2) the qualifications of the witness; and
- (3) the usefulness of the testimony to the jury