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DNA EVIDENCE

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I. INTRODUCTION

DNA profiling[1] is a powerful new technique which is likely to have considerable impact upon the New Zealand legal system. It is a method of identifying an individual by analysis of their unique genetic material. The development of DNA profiling tests has been heralded as revolutionary, and some have described it in terms such as:[2]

> the most potentially far-reaching scientific advance to offer assistance to the criminal justice system since the development of fingerprint analysis.

The principal strength of the new tests lies in their potential capacity to identify individuals with an accuracy that is unmatched by conventional methods of testing body samples. DNA technology promises to be particularly useful for identifying criminals in forensic investigations. Besides the claim of accuracy, an important advantage is that DNA tests can be performed on many samples which are unsuitable for analysis by other means because of small quantities or poor quality. DNA profiling is also useful for establishing relationships of parentage since DNA is biologically inherited from each parent.

Although DNA profiling was only discovered as recently as the mid-1980's, it has already gained widespread recognition and use overseas. Since its initial debut in court proceedings during 1987, DNA test results have been admitted in evidence in a great number of civil and criminal trials, particularly in Britain and the United States.

In New Zealand, DNA evidence is only just beginning to appear before the courts. The first criminal case in this country where such

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[1] DNA profiling is also known as DNA typing, DNA testing, DNA printing and DNA fingerprinting, although many people prefer not to use the last of those terms to avoid any association with conventional fingerprinting (i.e. fingertip patterns). This paper will avoid using the terminology "DNA fingerprinting" for this reason. Despite the fact that some of the above terms are patented or organisation-specific (see section 1.4, below p10), they are used here in a neutral sense.

[2] I Freckleton "DNA Profiling: Forensic Science under the Microscope" [1990] 14 Crim LJ 23, 23.

evidence was contested is *R* v *Pengelly*, which has recently been heard on appeal. The accused was found guilty of murdering an elderly woman by a High Court jury in April 1990. After the two week trial at Auckland, which was largely based on forensic scientific evidence, Pengelly was sentenced to life imprisonment by the presiding Judge.[3] As an interesting sequel to the High Court hearing, further DNA tests were carried out on the blood samples obtained from the crime scene. Expert analysis of these results was put before a Full Court of the Court of Appeal in August 1991.[4] The Court decided to admit the new evidence, but having regard to all the evidence in the case, it considered that no miscarriage of justice had occurred.

Apart from *Pengelly*, DNA evidence has appeared in New Zealand courts in a sprinkling of other recent cases, but in most of these instances, the actual DNA results have not been seriously challenged.[5] A few have been cases of disputed paternity[6], while the rest have involved serious criminal charges such as rape and sexual abuse.[7] A recurrent problem in the criminal cases is the issue of consent to the taking of body samples from the accused.

In addition, since late 1989[8] there have been a significant number of situations in New Zealand where the accused pleaded guilty to the

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3 (Hearing 27/3/90 - 6/4/90), HC, Auckland, T240/90, Thorp J. A pretrial ruling on the admissibility of the DNA evidence is reported at (1991) 5 CRNZ 674 (HC), Thorp J.

4 *R* v *Pengelly* unrep (23/8/91), CA, 85/90, Cooke P, Casey, Hardie Boys, Gault and McKay JJ, (noted at 14:33 TCL 6)

5 At least in the cases the author has been able to discover.

6 For example *Loveridge* v *Adlam* [1991] NZFLR 267 (FC), Inglis J, and *T* v *S* (Decision awaited; Hearing 26/7/91; parties names not yet publishable; see below n 53) FC, Lower Hutt, FP 517/88, Curruthers J.

7 For example *R* v *Montella* unrep (13/5/91), HC, Dunedin, T5/91, Williamson J, (sexual abuse on person under 12 years), (noted at 14:25 TCL 6 and [1991] BCL 15:1428), and *R* v *Martin* unrep (16/5/91), HC, Wellington, T131/90,6/91, Hillyer J, (sexual violation), (noted at [1991] BCL 12:1172). In these two cases the issues were consent and refusal to providing body samples. In *R* v *Montella*, the High Court actually excluded the DNA evidence linking the accused to a semen stain from the victim on grounds of consent, because the accused's blood sample had only been given for AIDS testing to allay the fears of the complainant's father.

8 According to the *Dominion*, Wellington, 12 and 16 September 1989, the police (in conjunction with the DSIR) were then in a position to begin extensively using DNA profiling of suspects. Testing in the *Pengelly* case was commenced in August 1989.

crime charged when confronted with DNA evidence. And in the civil context, DNA test results have been privately obtained on a number of occasion to resolve a paternity matter out of court. As these sorts of cases do not come to public attention, legal research is generally restricted to the examples which appear in the law reports or which are noted in official publications.

There is no doubt that lawyers and judges will be faced with DNA evidence with increasing frequency. While the technique has tremendous potential and while the reaction of the legal community has generally been "enthusiastic"[9], DNA profiling also presents some difficult questions about admissibility and reliability of the evidence. Since DNA tests will have a major impact on the outcome of a trial, the accuracy of the evidence needs to be carefully scrutinised.

Elsewhere there have been concerns that DNA tests may have been prematurely introduced into the court forum, before they have been adequately validated.[10] This might be less of a problem in New Zealand because our scientists have been able to observe the mistakes and advances made with DNA technology in other legal systems over the last few years. Nevertheless there is still a need to ensure the reliability of the results, as with all scientific evidence, if DNA profiling is to be routinely used in the law.

This paper provides an introduction to the process of DNA profiling and examines its treatment as evidence in a court. Moreover, it will address some difficulties likely to be encountered by the legal profession in a case involving DNA.[11] The problem is not so much one

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9 W C Thompson and S Ford "DNA Typing: Acceptance and Weight of the New Genetic Identification Tests" [1989] 75 Virginia LR 45, 46

10 For example concerns were expressed by the Californian Attorney General in January 1988: discussed by W C Thompson and S Ford, idem, and by A P Adema "DNA Fingerprinting Evidence: The Road to Admissibility in California" [1989] 26 San Diego LR 377, 378.

11 There is no attempt to cover all the areas of law relevant to DNA profiling. The constitutional issues of privacy and self-incrimination which are raised in obtaining body samples by legitimate means, are beyond the scope of this paper. For an introduction to this topic, see N Levy "DNA fingerprinting: Justification for blood sampling by force ?" (1988) submitted for LLB(Honours) at Victoria University of Wellington, M G Sloan "The privilege against self-incrimination and real evidence: old women and hermits go fox hunting" (1990) LLM research

of understanding a complex science, as one of knowing the right questions to put to the experts. The discussion in this paper seeks to alert the legal community to the problematic aspects of DNA evidence through both a consideration of the scientific principles and an evaluation of the cases. In summary, it is an attempt to provide a response to the following quotation:[12]

> The power of scientific evidence can be used to proper advantage only if it is evaluated with sufficient scientific literacy. If our law schools fail to address that subject, judges and [lawyers] ... should take it upon themselves to understand the rudiments of scientific method and the reasons why general acceptance on scientific question can be difficult to attain.

Part II of this paper describes in basic terms the DNA profiling technique and how the results are interpreted. The potential applications and limitations of DNA technology are also considered. Part III begins with a brief discussion of the general principles of expert testimony in relation to scientific evidence. Then there is an examination of particular issues raised by the nature of DNA evidence, with a focus on the comprehension and admissibility of such evidence. In Part IV the main cases from various jurisdictions which pertain to the subject will be analysed. Part V concludes the discussion.

While the focus of this paper is DNA, the sorts of problems encountered are common to evidence from all forensic sciences. This century has seen an exponential growth in the technology and insights offered by sciences such as fingerprinting, blood-grouping, chemical substance analysis, firearms examination and document examination.[13] While such evidence can play a critical role in the

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paper at Victoria University of Wellington, and *Compulsory Taking of Samples in Criminal Investigations* (Auckland District Law Society Public Issues Committee, Auckland, November 1988).

12 Thomas *Some Observations by a Scientist* (1986) (Symposium on Admission of Scientific Evidence), quoted in J J Barr "The Use of DNA Typing in Criminal Prosecutions: A Flawless Partnership of Law and Science ?" [1989] 34 NY University LR 485, 485.

13 For a very brief introduction to these forensic sciences, see J H Phillips and J K Bowen *Forensic Science and the Expert Witness* (The Law Book Co. Ltd.,

outcome of serious trials, by nature it is highly technical and easily misunderstood. Hence the way in which expert evidence is presented becomes extremely important.

II. DNA PROFILING

1. The Technique

In 1985 Professor Alec Jeffreys, a geneticist of Leicester University in England developed the technique of DNA profiling[14]. The basis of the procedure is that genetic material (DNA) is extracted from blood or other body tissue and reacted with a "probe" to produce a pattern of bands of stripes which is specific to that individual.

Under the conditions of Professor Jeffreys' experiment,[15] the chance of two unrelated[16] people having identical profiles was roughly 30,000 million to one. Comparing the population of the world, which is approximately 5 billion[17], DNA profiling has a very strong power to discriminate between individuals. Under other methods the chance of a coincidental match has been asserted to be one in many millions.[18] Thus under ideal conditions, DNA tests can be used to positively identify people and establish family relationships with virtual certainty. Herein lies its enormous potential for the law.

Victoria, revised edition including appendix on genetic fingerprinting, 1989), part II.

14 DNA itself was discovered long ago, although most scientific progress has been made in the last few decades. Since the 1970's DNA has been used in the study of human genetic diseases (e.g. cystic fibrosis), which is commonly referred to as DNA diagnostics.

15 Reported in A J Jeffreys, V Wilson and S L Thein "Individual-specific 'fingerprints' of human DNA" (1985) 316 Nature 76. Three different multi-locus probes were used on samples from a panel of 20 unrelated British Caucasians.

16 Although not necessarily randomly selected.

17 The world population in 1990 was estimated at 5,286 million: S J Young "Current Topic: DNA Evidence - Beyond Reasonable Doubt ?" [1991] Crim LR 264.

18 The power of identification has been asserted to be one in 840 million and one in 140 million (Black Americans) (by Lifecodes in *People* v *Wesley* 140 Misc 2d 306; 533 NYS2d 643 (albany CCt 1988), and even as high as one in a trillion, however many commentators believe these statistics are exaggerated: see generally J J Barr, above n 12, 488 and A Pearsall "DNA Printing: The Unexamined 'Witness' in Criminal Trials" [1989] 77 California LR 665, 668.

What follows in the next few sections is a brief background to the science and the testing procedures involved in DNA profiling. This treatment is very much a simplified overview for the lay reader.[19]

1.1 What is DNA ?

Almost every tissue and fluid in a person's body contains the substance deoxyribonucleic acid (DNA). It is the genetic material contained in the nucleus of all living cells from which chromosomes are made. DNA stores the genetic information which makes every individual unique. According to some estimates, about 90 percent[20] of genes are the same in all people, while the rest vary from person to person. Other estimates assert that about two thirds of human genes are the same.[21] Either way, there is an almost inconceivably large number of combinations of genes in the human body. The only exception is the case of identical twins, who will have identical DNA.

An individual inherits DNA from his or her parents, with approximately half being contributed by the mother and half by the father. While parents do not impart the same 50 percent of genes to each of their children, related people share a significant proportion of their DNA. It has been estimated that with siblings, 63 percent of their DNA profile bands would match.[22] It is an important quality of DNA that it is the same throughout a person's body, and it remains the same throughout their life.

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19 This information is drawn from a number of sources designed for the non-scientist, which should be consulted if a more comprehensive treatment is required: K F Kelly, J J Rankin and R C Wink "Method and Applications of DNA Fingerprinting: A Guide for the Non-Scientist" [1987] Crim LR 105, J J Barr, above n 12, W C Thompson and S Ford, above n 9, J C Hoeffel "The Dark Side of DNA Profiling: Unreliable Scientific Evidence meets the Criminal Defendant" [1990] 42 Stanford LR 465, L Beeler and W R Wiebe "DNA Identification Tests and the Courts" [1988] 63 Washington LR 903, I Freckleton, above n 2, J J D Greenwood and R M White "DNA Fingerprinting and the Law" [1988] 51 Modern LR 145, C M Tande "DNA Typing: A New Investigatory Tool" [1989] Duke LJ 474.

20 J J Barr, above n 12

21 J J D Greenwood and R M White, above n 19, 145

22 P Macalister "From fingerprints to genetic codes: Indisputable evidence ?" (1989) Law Society Journal (Aust) 43, 45

DNA is composed of two long strands of alternating sugar and phosphate units. The strands are linked by paired molecules called *bases* of which there are only four kinds, represented by the letters A, T, C and G. It is the particular sequence of these bases that is unique for every person and creates their genetic code. Each chromosome contains millions of pairs of bases.

Repeated sequences are known as *minisatellites* and the number of repeats is characteristic of the individual. *Allele* is the genetic term which refers to the variations that occur in a region of DNA. The strands of DNA twist around each other in a spiral to form a *double helix*. The structure of DNA is said to look something like a twisted ladder. Alternatively, the sequence can be envisaged as a zipper in which the "teeth" only close when the bases are paired in a particular way (A-T, G-C).

1.2 The Process of DNA Profiling

The technique for obtaining a DNA profile is a complex scientific procedure. It is a labour intensive process that requires meticulous expertise. The steps involved are set out here in summary form.[23]

1. The starting point is obtaining a biological sample. With few exceptions,[24] DNA can be extracted from any human body tissue or fluid. Most often a sample consists of blood, semen (with spermatoza), skin, or hair roots.

2. Quite small quantities are said to be sufficient for DNA testing. Most authorities say that the tests can be done on smaller samples than those required for conventional bloodgrouping tests.[25] Current DNA

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[23] These steps are usefully summarised in diagramatic form by P Stringer and S Cordiner "DNA Profiling" (1989) 2 Family L Bulletin 10, 12, and by B Selinger and E Magnusson "The Scientific Basis of DNA Technology" in *DNA and Criminal Justice: Conference Proceedings* by J Vernon and B Selinger (eds) (Australian Institute of Criminology, Canberra, 1990, No. 2) (Conference held 30-31 October 1989).

[24] Red blood cells (which do not have nucleii) are one of the few exceptions. Apparently over 90 percent of the cells in the human body contain DNA: J J Barr, above n 12, 494 (fn43).

[25] For example, see J J Barr, above n 12, 514.

technology requires something like a minimum of 50 microlitres (0.05 millilitres) of blood, 10 microlitres of semen or 10 hair roots[26], although larger samples will be taken if possible to ensure there is enough to perform the tests. There are, however, conflicting claims in some of the literature about the quantities required.[27]

3. The DNA is extracted and purified by chemicals so that only DNA remains. If the sample is small it is common to use a technique to estimate how much DNA there is to work with.

4. Next the DNA is treated with an enzyme known as a *restriction enzyme* (or *restriction endonuclease*). This cuts the DNA into fragments of different lengths at points where the enzyme recognises a particular base sequence or code. The scientist can control the regions which are cut by using a certain enzyme.

5. The fragments are placed in an agar gel so that they can be sorted by length. An electric current is run through the gel in a process called *gel electrophoresis*. The current causes the fragments to migrate down the gel towards the positive electrode, with the more mobile, shorter fragments moving faster than the longer ones. Thus the DNA fragments are arranged in bands throughout the gel according to their size or molecular weight. The DNA is invisible, but there are methods of checking that the sample has "run down the track properly" (e.g. using dye).

6. Samples of DNA from different sources are run through the gel in lanes next to each other. It is normal for one of the lanes to be a *control lane*. This is a sample of DNA from a known, unrelated source, used as a comparison because its length, and the strength of its result for the particular probe used, is predetermined.

7. The DNA is transferred to a nylon membrane by blotting it from the gel using a process known as *Southern Blotting*. The DNA

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26 I Frecktelton, above n 2, 28

27 For example D Werrett and J Lygo say in "DNA Profiling" (1987) The Law Society's Gazette 3637, at 3638 that "[t]he amount required is much greater than for conventional tests".

fragments become fixed to the membrane, which is easier to work with than the gel.

8. A *probe* (or a series of probes) is then applied to the membrane to detect regions of DNA that vary greatly between individuals. Probes are special pieces of DNA in a solution which has been pre-treated to make it radioactive. The probe will recognise a particular sequence of DNA bases (minisatellite), and bind (*hybridise*) to fragments of this sequence in the DNA pattern. In this way the probes act as markers.

9. Next the membrane is placed against an X-ray film, and the radioactivity causes an image of bands to be recorded on the film. This stage normally takes several days, but can take up to several weeks.

10. When the film is developed, the result is a picture (*autoradiograph* or *autorad*) which roughly resembles the barcode found on supermarket packaging.[28] This is how an individual's unique DNA profile is recorded.

The profiles from different DNA samples are now ready for the complex step of comparing the bands for identification and interpreting the results.

1.3 Multi-locus probes and Single locus probes

At present, there is no consensus or uniformity amongst the world's DNA laboratories as to the best type of probe to use. The two main categories of probes are called *multi-locus probes* and *single locus probes*.[29]

A single locus probe binds to only one particular sequence of DNA bases. It will produce a profile containing one or two bands only. If it reveals one band, it is most likely that the person inherited this same

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[28] There are some realistic visual examples in J Lygo "Sharpening the Focus" (1991) 141 New LJ 448, and in D Werrett and J Lygo "The role of DNA Profiling in the Courts" (1989) The Law Society's Gazette 13:35 (5 April).

[29] A *locus* is the general term to describe a particular site on the DNA molecule.

allele from both parents. The advantage of using single locus probes is that they are highly sensitive and generally produce strong bands. Their disadvantage is that they produce relatively low discrimination, with results commonly being able to distinguish only one in hundreds. If there is enough DNA, this can be overcome by using a series of about 3 or 4 separate probes on the same sample and combining the results.

Multi-locus probes bind to a number of base sequences that are similar but not identical. They produce profiles composed of bands in a barcode pattern. The number of bands usually ranges between 15 and 40, and not all of the bands will have the same intensity. The advantage of using multi-locus probes in that they provide more information per profile, and they can produce highly discriminatory information, often in the order of one in millions. Their disadvantage is that they are relatively insensitive compared to single locus probes, and for this reason a larger amount of DNA is required.

Sometimes it is possible to do repeated tests on the same sample of DNA, which would allow analysis with several different probes, and even a combination of multi-locus and single locus probes. The probe can be removed from the nylon membrane by washing in a process known as *stripping*. Unfortunately when the membrane is stripped, an amount of DNA will be lost, and therefore the sensitivity of the tests is reduced with each re-probing.

With each set of DNA samples the scientist must assess which probes will produce the most effective result. This is heavily dependent on the quantities of the samples, the probes available to that laboratory, and whether they have adequate population data.[30]

1.4 The Testing Laboratories

DNA testing techniques are marketed by two main commercial laboratories. The patent for the multi-locus probe method developed

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[30] Section 3.3, below p 26

by Dr Jeffreys is held by ICI[31] in the United Kingdom, who formed Cellmark Diagnostics Corporation in 1987 to market the technique on a commercial basis. Soon afterwards Cellmark also began to operate through a subsidiary in the United States.[32] The company have coined the term "DNA Fingerprinting" to describe the testing system. When Cellmark first opened they relied exclusively on multi-locus probes, but since early 1988 the company have used some single locus probes as well, particularly for criminal identification work.

The other predominantly used test is a single locus probe method offered by Lifecodes Corporation in the United States[33] since 1987. The patented term used by this company is the "DNA-Print Identification Test". Generally, up to four single locus probes are used to produce one or two bands each. Lifecodes' testing method has been widely used in the United States from the outset, while the Jeffreys muli-locus probes are said to have been "little employed in the USA".[34]

In addition to those two main testing methods, Cetus Corporation in the United States[35] has developed a DNA test known as "Polymerase Chain Reaction" (PCR), or "DNA Amplification". This process is markedly different from the Lifecodes and Cellmark tests in the procedures used,[36] and in the fact that it produces a pattern of dots from which an individual's genetic information can be determined. It has the advantage of requiring far less biological material than the other tests[37] since the amount of DNA is "amplified". However, in

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31 Imperial Chemical Industries, a multi-national chemical and pharmaceutical company.

32 Cellmark Diagnostics is now based in Adingdon, Oxfordshire in England, and Germantown, Maryland in the United States.

33 Lifecodes is based in Valhalla, New York.

34 Paper by Dr A R Bellamy (9/11/90), received in correspondence with Dr P Stapleton, below n 44.

35 Cetus Corporation is based in Emeryville, California.

36 The Lifecodes and Cellmark techniques are classified as *restriction fragment length polymorphism* (RFLP) analysis, while the PCR technique is an *allele-specific probe analysis*. For detailed discussion on the difference between these procedures, see W C Thompson and S Ford, above n 9, 64-79 and J J Barr, above n 12, 497-508.

37 It is said that the Cetus test can type a single hair root or as few as 40 sperm heads, (compared to several thousand sperm heads required by other tests): Higuchi, von Beroldingen, Sensabaugh and Erlich "DNA Typing from Single Hairs" (1988) 322 Nature 543, cited by W C Thompson and S Ford, above n 9, 50.

comparison this test produces less specific results, and relies on technology which is "newer and perhaps less widely accepted."[38]

The technique used by the Federal Bureau of Investigation (FBI) in the United States[39] is also "unique". The probes it uses are a blend of probes drawn from those used by the other private laboratories. "DNA Profiling" is the term used by the FBI.

As molecular biology advances, other methods of DNA profiling are sure to be developed. Forensic scientists have already begun experimenting with a new approach to testing using a laser sequencing technique.[40]

In New Zealand, DNA testing for the police, along with most other forensic investigation work,[41] is presently carried out by the Department of Scientific and Industrial Research (DSIR). The DNA probes discovered by Jeffreys are among those that the DSIR presently use. Research currently being undertaken by their DNA technicians should enable greater use of single locus probes in the near future The DSIR are also working on the introduction of DNA amplification technology, so as to make their tests more sensitive.

The Jeffreys method is also applied by the police scientific laboratories in the United Kingdom,[42] including the Home Office Forensic Science Service with which the New Zealand DSIR Chemistry Division has close connections. The Home Office have recently begun to use single locus probes as well, since population data has become

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38 W C Thompson and S Ford, above n 9, 50.

39 The FBI has established its Forensic Science and Research Training Centre in Quantico, Virginia. See K W Nimmich "Structure of the FBI Laboratory" in *DNA and Criminal Justice: Conference Proceedings*, above n 23, at 85 on the FBI's research programme. FBI casework analysis began in December 1988.

40 See J J Barr, above n 12, 493 (fn 36) for details.

41 Apart from conventional fingerprinting, which has long been a specialised branch of police work.

42 The Central Research and Support Establishment of the Home Office Forensic Science Service (at Aldermaston), the Metropolitan Forensic Science Laboratory (in London) and the Northern Ireland Forensic Science Laboratory.

available. State Forensic Laboratories in Australia use the Lifecodes testing method.[43]

There are four private testing laboratories available to conduct tests for civil disputes in New Zealand.[44]

i) DNA Diagnostics Ltd, which was the first private laboratory to offer testing here, operates within the School of Medicine at Auckland University.[45] Their DNA profiling service uses the Jeffreys probes as well as a combination of single locus probes. DNA Diagnostics does not conduct conventional bloodgrouping tests on the samples they analyse.

ii) The Auckland Regional Blood Transfusion Centre, have performed conventional blood tests for parentage disputes for many years, and continue to do so. They announced the availability of DNA technology early in 1990.

iii) The Otago Regional Blood Transfusion Centre, began performing DNA profiling early in 1991, in addition to well-established conventional blood testing.

iv) Genetic Technologies Corporation, situated in New South Wales, Australia, is the appointed licensee of Lifecodes Corporation for Australia and New Zealand.

These private laboratories charge somewhere around NZ$1000 for a set of tests on three individuals.

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[43] See D Gidley "DNA Profiling: The Transition from Watching Brief to the Courts -a Victorian perspective" in *DNA and Criminal Justice: Conference Proceedings*, above n 23, at 97, for a comment on why they adopted the Lifecodes method. Their DNA profiling casework service began in July 1989.

[44] Contacts for correspondence are:
(i) Dr P Stapleton, Technical Manager, DNA Diagnostics Ltd, PO Box 5739, Auckland.
(ii) Dr J M Faed, Director, Otago RBTC (Dunedin Hospital).
(iii) Dr D G Woodfield, Medical Director, Auckland RTBC (Auckland Hospital).
(iv) M Jones, Marketing Director, Genetic Technologies Corp. (Artarmon, NSW 2064).

[45] In fact it is joint venture of Auckland Uniservices and Diagnostics Laboratory Holdings Ltd.

2. A Comparison with Conventional Tests

Until the development of DNA profiling, blood sample testing was limited to several bloodgrouping systems based on some principal ways in which the blood of one human can differ from another. These are:[46]

i) The "ABO" blood grouping system, which tests blood cell membranes for the presence or absence of antigens A and B.[47] This system is the oldest of conventional testing methods, and also the most important for forensic purposes because it is capable of being detected in dried bloodstains. The "HLA" system is another antigen-testing method.

ii) Systems which indicate antibodies and proteins present in the blood serum, such as the Hp protein.

iii) Systems which classify different enzymes found in blood cells. Examples are the PGM, AK, and EAP classification systems.

iv) Tests on other body fluids such as perspiration, saliva, vaginal secretions, and semen to determine whether the individual secretes antigens into these fluids.[48]

It is often said that conventional blood grouping methods have only ever been able to exclude a particular person as a putative criminal or biological parent, not positively identify them. The following statement is an example.[49]

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46 See J H Phillips and J K Bowen, above n 23, ch 6, or J H Phillips "Genetic Fingerprinting" [1988] 62 Aust. LJ 550. The figures quoted in the next two footnotes, taken from those sources, are estimates for the Australian population, although the New Zealand population is expected to be very similar.

47 About 46% of the population belong to blood group "O"(antigens A and B both absent), 38% to group "A" (antigen A present, B absent), 13% to group "B"(antigen B present, A absent), and 3% to group "AB"(both antigens present).

48 About 78% of the population are secretors.

49 S J Cordiner and P Stringer "Getting into your genes" (1986) 1 Family L Bulletin 82, 82

> Current methods of characterising such body fluid stains are limited in that they only allow the scientist to say that the stain could have come from a certain percentage of the New Zealand population, never that it came from a particular person.

By way of comparison, claims have been made that DNA profiling "[has] the advantage of providing positive proof of paternity"[50], and that "the discriminating power of the technique is such that positive associations can be made."[51]

In fact the concepts of conventional blood testing and DNA profiling are not fundamentally different, even if the details of the testing procedures are. The essential difference between them is in the magnitude of the identification statistics that result. What DNA technology offers is not *absolute* proof of identity, but results which can approach such a high level of accuracy that they are said to produce virtual certainty, or "nearly positive identificaton."[52]

Perhaps then, DNA tests are best regarded as simply another type of blood testing, albeit potentially much more sensitive. This is the precise question that has recently come before a Family Court Judge for determination in a paternity case.[53]

Conversely, others would prefer to see conventional blood tests as a type of DNA testing.[54] An argument can be made that conventional blood tests are *indirect* tests of DNA, since the characteristics of cells and tissues that they are designed to test are actually determined by

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50 S Maidment "DNA Fingerprinting" (1986) 1 Family L Bulletin 83, 83

51 P Stringer and S Cordiner, above n 23, 10

52 C M Tande, above n 19, 480

53 *T* v *S*, above n 6. The mother made a formal application under section 55 of the Family Proceedings Act 1980 for further paternity tests to be done, after conflicting results were obtained from earlier DNA and blood typing tests performed by Auckland Regional Blood Transfusion Services. This Family Court hearing concerned the preliminary issue of whether DNA tests are in fact blood tests within the meaning of sections 54-59 of the Family Proceedings Act. A DSIR scientist gave evidence at the hearing that a DNA test is a type of blood test.

54 This view is held by J M Faed and A E Knight "Testing for Paternity" (Otago Regional Blood Transfusion Centre, Dunedin, 7 December 1990), 2.

DNA. Under this analysis, the new DNA profiling tests are a direct way of testing DNA characteristics.

In forensic science, bloodgrouping tests are just one type of evidence that has traditionally been used to connect a suspect with some crime. Any number of samples of biological and chemical "trace material"[55] might be retrieved from the crime scene, or from victims and suspects. The forensic biologist may, for exmple, be asked to identify and differentiate hairs, fibres, or other body fluid stains such as saliva. The same evaluative principles behind DNA profiling and bloodgrouping methods also apply to these other sorts of evidence. Depending on the nature of the particular biological material, the discriminating power of the statistical result may be of great probative value, very little, or none at all.

Conventional fingerprint evidence[56] is a specialised analysis of "trace material", but again the underlying principles are not really any different. It has been estimated that the number of possible fingerprint patterns is 64 billion[57], hence fingerprint comparisons have acquired the "colloquial specificity of absolute identification."[58] It is no doubt because of this high power of individualisation that the term "DNA fingerprinting" has been used to describe the new DNA technology at times.

The main thing that does differentiate fingerprint evidence from DNA profiling[59] is the way in which the evidence is normally

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55 The relevance of all forensic scientific evidence theoretically arises from the age-old "contact trace" principle from Locard, that any two objects in contact will leave some trace.

56 For an introduction to fingerprint analysis and its historical background, see J H Phillips and J K Bowen, above n 13, ch 8.

57 But note that estimates of the probability of two people have identical fingerprints vary according to the classification system used: see B W N Robertson "Fingerprints, Relevance and Admissibility" [1990] NZ Recent LR 252, 254.

58 D A Stoney "What made us ever think we could individualise using statistics?" (1991) J Forensic Science Society 197, 197.

59 It is worth noting a further difference between these two sorts of evidence which has recently been argued. D A Stoney, idem, points out that while the process of comparing fingerprints is "explicity a subjective process", DNA profiling is based on the more objective "step-wise" disciplines of population genetics and statistics. Having said that however, he acknowledges that there is

presented. Fingerprint experts speak in terms of a "number of points of comparison", while the other evidence is generally given as a probability or likelihood. This distinction is largely historical, and its desirability has recently been questioned.[60]

3. Interpreting DNA Results

There are two necessary steps in comparing the profiles from different DNA samples. The first is matching bands, and the second is explaining the results in statistical terms. It is not meaningful to perform one step without the other. This may seem very elementary, but more than one Judge has managed to surprise in a DNA case by admitting evidence of only one of the steps.

3.1 Matching bands

The profiles produced in laboratories rarely have the crisp, clean appearance of the familiar supermarket barcode with which they are likened. Especially for multi-locus profiles, the bands are often smudgy, smeared or faint, making it difficult to determine where one band starts and another ends.

In criminal investigation work, the band matching task is often made particularly difficult by a blurry or faint appearance of bands in DNA profiles, caused by an insufficient quantity of sample. Samples that are contaminated or degraded can also result in smearing, or they might cause bands to be missing or extra bands to appear.[61] Contamination by the presence of bacteria or organic material can

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still some human judgment involved, and that DNA profiling cannot lead us through to "absolute identifications".

60 B W N Robertson has suggested that the preferable approach with regard to fingerprints is for the evidence to be given in both forms, ie. for the "number of points of comparison to be accompanied by evidence ... as to its probabilistic effect": see above n 57, at 257, in a comment on New Zealand's leading fingerprint evidence case (*R* v *Buisson & Ratana* [1990] 2 NZLR 542 (CA)).

61 There is some debate amongst scientists about how common it is for "extra" bands to appear as a result of contamination-type problems. It has been pointed out that: "the aberrations are far more likely to make matching DNA prints look different than to make different DNA prints look the same." However, extra bands have been known to appear before. See W C Thompson and S Ford "Is DNA fingerprinting ready for the Courts ?" (1990) New Scientist 20 (31 March),23.

occur at any stage of the DNA testing process, or during collection and handling of the samples[62], or commonly before collection if the specimen is from the scene of a crime.

There is also a phenomenon known as "band shift", in which samples from the same individual produce similar DNA prints, but with the bands out of alignment. This is caused by a different migration rate of DNA in different lanes during *gel electrophoresis*, which has been attributed to a number of factors.[63] The important point for present purposes is the established fact that band shifting can occur even if the various lanes contain DNA from the same individual. So the scientist must look to see if a non-alignment was uniform. Practices adopted to overcome these sorts of problems obviously add a significant element of subjectivity to the interpretation of results.

(a) Criminal Identification

The bands produced by different samples on an autorad should *theoretically* be in identical positions if the samples come from the same source. Thus in forensic investigation, the technician is attempting to establish band "matches". Decisions are based on visual comparison and precise measurement. Mechanical measuring devices are available, but their reliability is not yet widely accepted.

In the case of single locus probe analysis, two bands are traditionally declared a match if they are within a specified distance or standard deviation of each other, which is known as the *binning* approach. This method of declaring matches leads to a definite cut-off point, outside which a band is a non-match. No allowance is made for "close matches". Tiny differences in band positions could tilt the evidence from incriminating to excluding. This is, of course, of great concern when one considers the possibilities of complications such as "band shift".

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62 See generally, T Sargant and P Hill *Criminal Trials: the Search for the Truth* (Fabian Society, London, 1986) (Fabian Research Series No. 348).

63 See P J Neufeld and N Colman "When Science Takes the Witness Stand" (1990) 262:5 Scientific American 18, 23, and E S Lander "Invited Editorial: Research on DNA Typing Catching up with Courtroom Application" (1991) 48 Am. J Human Genetics 819.

This problem of declaring matches and non-matches has been highlighted by several authors.[64] As a solution, scientists and statisticians from Britain and New Zealand[65] have recently devised a way of assessing the quality of a match. The position of the bands is treated as a continuous variable under this method. Thus the value of the evidence, or the "match", becomes progressively stronger as the bands come closer together.

In the writer's view, the continuous model of establishing band matches seems to be preferable to a "matching rule" in logical terms. But the approach is relatively new and has not been extensively reviewed in the literature. Furthermore, extensive "properly designed"[66] studies have been recently carried out in the United States, which support and validate the use of the fixed bin method of declaring matches. On the basis of these studies, the FBI have collated a massive database to be used to interpret the significance of bands that "match".[67]

With multi-locus probes, where there are a greater number of bands in each profile, the comparison will be mostly visual. The intensities and overall pattern of the bands is as important here as the distances between corresponding bands. All the bands in the scene sample must be present in the suspect's profile, otherwise most laboratories will declare a non-match. Remember that the scene sample profile is likely to be of poorer quality than the profiles of individuals that it is being compared with.

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64 Discussed in J Lygo, above n 28, 448. Another useful summary of the problem is in I W Evett "Evaluation of DNA Profiles: sense and nonsense" (1991) J Forensic Science Society 205.

65 J Lygo, idem, I W Evett, idem, and J Buckleton, C M Triggs and K A J Walsh "An approach to the interpretation of DNA locus specific work based on a continuous model for the position of DNA bands" (DSIR, Auckland, 1991) (Publication in the J Forensic Science Society forthcoming).

66 E S Lander, above n 63, 820. He asserts that they are the "first properly designed studies to support a matching rule".

67 B Budowle, A M Giusti, J S Waye et al, "Fixed-Bin Analysis for Statistical Evaluation of Continuous Distributions of Allelic Data from VNTR Loci, for Use in Forensic Comparisons" (1991) 48 Am. J Human Genetics 841, and B Budowle et al (FBI) "A Preliminary Report on Binned General Population Data on Six VNTR Loci in Caucasians, Blacks and Hispanics from the United States (1991) 18:1 Crime Laboratory Digest 10.

It is a moot point whether two multi-locus profiles must be absolutely identical to be of any probative value as evidence. Many scientists hold that it is in the nature of laboratory testing that results will hardly ever be exactly identical. If this is so, then:[68]

> an expert who insists that DNA prints be identical in all respects before declaring that they match, will miss a lot of matches ... the cutoff point for declaring a match must be at some level short of a perfect correlation.

It must be acknowledged that this method of matching multi-locus probes is highly conservative. In theory it should be possible to devise a mathematical model which assesses the quality of a match for each multi-locus profile band similar to the one described above for single locus probes. Such a model, which would be extremely complicated, has not yet been designed.

(b) Parentage

If the DNA tests instead seek to establish a relationship, the technician examines whether a child's profile can be obtained by combining the bands from each of the parents' profiles. Despite this fundamental difference, the process of declaring band matches between profiles is based on essentially the same principles.

Quantity and quality of the samples do not tend to cause any problems in issues of parentage since adequate samples can usually be taken at any time. There are, however, exceptions, such as the need to establish a relationship for the crime of incest.

3.2 Statistics

The outcome of a DNA test is expressed as the probability or chance of a coincidental match, or in other words, the likelihood that by chance another randomly selected individual will have exactly the

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68 J J Barr, above n 12, 516 (quoting from Thompson and Ford).

same DNA pattern. The actual statistics can vary greatly from test to test since they depend upon which probes and enzymes are used, as well as the quality of the samples.

It follows from what was said earlier, that the finding of a "match" in forensic science is, on its own, a piece of misleading and meaningless evidence. It can only make any sense if the chance of a match in the general population is compared. One of the few commentators to have enunciated this states:[69]

> A match is only significant, however, if one knows how often two people's profiles match by chance. To make that calculation, scientists *must* know how often a particular profile occurs in the population.

What sort of statistical analysis is used to achieve this comparison ? The Bayesian approach provides a widely recognised and useful basis for the statistical assessment of evidence in forensic science.[70] Bayes rule describes how probability changes on the receipt of new information, and it can be used to quantify the presentation of evidence. Bayesian probability theory is based on the ability to quantify uncertainty. This means that if all pieces of evidence were able to be ascribed a mathematical probability, Bayes rule could produce a final estimate of the probability of criminal guilt, for example. Of course human intuition does not quantify most pieces of evidence with numerical precision. Forensic evidence is perhaps an exception. Even so, "Bayes theorem still reproduces qualitatively just what your common sense tells you".[71]

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[69] C Joyce "High profile: DNA in Court again" (1990) New Scientist (21 July), 10 [own emphasis]

[70] Support for this approach can be found in J Lygo, above n 28 (and the citations therein), J Buckleton, C M Triggs and K A J Walsh, above n 65, M O Finkelstein and W B Fairly "The Continuing Debate over Mathematics in the Law of Evidence" (1971) 84 Harvard L R 1801, S E Fienberg and M J Schervish "The Relevance of Bayesian Inference for the Presentation of Statistical Evidence and for Legal Decisionmaking" [1986] 66 Boston LR 771, I W Evett "What is the probability that this blood came from that person ? A meaningful question ?" (1983) 23 J Forensic Science Society 35, and I W Evett "Bayesian inference and forensic science: problems and perspectives" (1987) 36 The Statistician 99.

[71] E T Jaynes *Probability Theory - the Logic of Science* (Washington, draft 1991) (Publication forthcoming), at 113

In mathematical terms, Bayes theorem states:

$$\frac{P(G/E)}{P(G/E)} = \frac{P(E/G)}{P(E/G)} \times \frac{P(G)}{P(G)}$$

where G = guilt and E = evidence. The first component, an assessment of the probability of guilt compared to the probability of non-guilt (innocence), is the business of the court. The third component is the court's previous or *prior* assessment of guilt before the new piece of evidence (E) was received. The second component is known as the *likelihood ratio* of the present piece of evidence, stated as a ratio of 1 to some other number. This is the concern of the expert witness.

The application of the Bayesian approach to legal decisionmaking is not without criticism.[72] An alternative mode of analysis is offered by a contrasting school of statistics known as the frequentist approach. Mathematically, this requires an estimated frequency stated within some level of confidence. Often the results produced by this analysis will be the same as those from the Bayesian likelihood ratio, but not always.

Specifically in relation to DNA profiling for criminal investigation work, the likelihood ratio is widely considered to be a very useful way of analysing and presenting the evidence. DNA results are now interpreted using this method by the New Zealand DSIR, and also by the Home Office, as the result of organisation policy decisions.[73] Unfortunately the giving of evidence in cases of paternity has not been so uniform.

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[72] Much debate has been generated about the relevance of different mathematical models to the law of evidence. A chief critic of the Bayesian approach is L H Tribe "Trial By Mathematics: Precision and Ritual in the Legal Process" (1971) 84 Harvard LR 1329. Others are mentioned in S E Fienberg and M J Schervish, above n 70, which is a useful pro-Bayes article which summarises the main objections to Bayes theorem and attempts to address the critics.

[73] Interestingly, and by way of contrast, the DSIR has always presented traditional bloodgrouping evidence in frequentist terms.

It is suggested in this paper that the likelihood ratio is indeed a very useful form of interpreting and presenting DNA evidence. Several general reasons can be given for this.[74] It can help the expert identify all the relevant issues, and it can also help the court to properly understand the evidence and combine it with all the other evidence in the case. Exactly why this is so should become clearer in the next few sections, where the nature of the actual statistical calculations on the basis of Bayes rule will be briefly outlined.

The likelihood ratio specifically requires the expert witness in a criminal case, for instance, to consider the probability of "these" DNA bands (E = evidence) given that the stain comes from the suspect (C = contact)[75], divided by the probability of the bands (E) given that the stain does not come from the suspect (C).

$$\frac{P(E/C)}{P(E/\overline{C})}$$

(a) Criminal Identification

(i) Single locus probes

The likelihood ratio of Bayes Theorem is directly useful for interpreting DNA profiles from single locus probes.

The Numerator

At first sight, *the probability of the evidence given contact by this accused* is expected to be 1 if it represents a "match", and 0 if it represents a "non-match". However, the practical problem of band shift, which has already been raised, is likely to cause small differences in position between corresponding bands, even between

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74 The reasons which follow are suggested by B Robertson and A Vignaux "A Bayesian in the Witness Box" (Proceedings of the Annual Conference of the New Zealand Statistical Association, Wellington, 28-30 August 1991) (Publication forthcoming). Giving evidence in the form of likelihood ratios is canvassed in more detail later: section 5.5, below p 39.

75 Scientists prefer to replace G with C = contact, since it is not their job to consider guilt.

two profiles from the same individual. The method described above[76] for calculating the quality of a match, is designed to remedy this problem. If that model is used, then the numerator of this ratio will not be exactly 1 in most cases of a "match", but something close to 1. The further apart two corresponding bands, the smaller the numerator, and the smaller the likelihood ratio for the DNA evidence.

But this new model of analysis has not been universally adopted. Hence the traditional match/non-match ideology that derives from the binning method is still frequently encountered in written works. Consider this statement for instance:[77]

> If, by comparison, a sample obtained from a suspect matches, then there will be a probability closely approximating 100% that the samples came from the same individual. A non-match can be safely assumed to indicate the contrary.

The Denominator

The denominator requires *the probability of the evidence given that the stain does not come from the suspect.* In other words, it is assumed that it could have come from "anybody else". Thus the chance of the profile originating from a randomly selected member of the population usually needs to be considered. Such data can only be obtained from population surveys. The rarer the bands in the DNA profile, the lower the denominator, and the higher the likelihood ratio.

The population that the accused is being compared with should not necessarily be the whole population. If it is only a subset, this might mean that different population data applies, and it should affect the court's understanding of the likelihood ratio.

The issue of which database to use in a given case appears to cause some confusion. It is submitted that a comparison with some subset of

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76 Section 3.1, above p 18

77 J H Phillips and J K Bowen, above n 13, 110

the general population should only be made when the inquiry has revealed some reason to do so. The point is aptly stated by Evett in this way:[78]

> There is evidence that some practitioners ... believe that the relevant population is that to which the suspect belongs. This is wrong ... the most appropriate database is determined by the circumstances of the offence.

Thus if there was an eyewitness who testifies that the perpetrator was a Maori, then the frequency of finding a particular DNA profile band amongst the Maori population becomes relevant. In the absence of this sort of connection to the incident, there is no logical reason why a particular accused's DNA profile (even if a Maori) should be compared with anything except the general population.[79]

It is therefore necessary, for reasons of clarity, to state the hypothesis represented by the denominator of the likelihood ratio, in positive and specific terms.

> Experts should neither inflexibly nor covertly assume a particular alternative hypothesis, but should be able to give evidence on the basis of the alternative hypothesis appropriate to the particular case.[80]

(ii) Multilocus probes

From population studies, the chance of any one multi-locus profile band occurring in another randomly selected person's profile is estimated to be 0.26 or slightly less.[81] That is, approximately 1 chance

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78 I W Evett, above n 64, 206. Also see J S Buckleton, I W Evett and K A J Walsh "Who is 'random man' ?" (DSIR, Auckland, and Home Office, United Kingdom, 1991) (Publication in J Forensic Science Society forthcoming), at 4.

79 The definition of the correct target population is also a major issue in frequentist analysis: see C Kingston "A Perspective on Probability and Physical Evidence" (1989) 34 J Forensic Sciences 1336.

80 B Robertson and A Vignaux, above n 74

81 The figure of 0.26 was originally devised by A R Jeffreys, J F Y Brookfield and R Semeonoff in "Positive identification of an immigration test-case using human DNA fingerprints" (1985) 317 Nature 818. It has been validated in New Zealand

in 4. The chance of two bands matching is therefore[82] 0.26 x 0.26 (or 0.26^2), which gives a ratio of 1 in 15. The chance of three bands matching, 0.26 x 0.26 x 0.26, is 1 in 59, and so on. This derives the formula,

$$0.26^x$$

where x = the number of bands that match above a certain height marker on the profiles. This has become an accepted way of calculating the likelihood ratio for multi-locus probe profiles. Notice that the single formula incorporates both the numerator and the denominator of the Bayesian ratio.[83]

(b) Parentage

The approach to interpreting DNA results in paternity or other parentage testing has been greatly influenced by the way in which conventional bloodtesting evidence is assessed. Generally the analysis is divided into two stages. Apparently, however, the methods used in New Zealand for statistical analysis of paternity results differ between laboratories.[84]

At the first stage, the percentage of random males who are *excluded* from paternity is calculated. This is derived from the results of tests on the mother, the child, and the general population. This statistic provides a critical indicator of the "ability of the set of tests to exclude males who are not the true father."[85]

Where an alleged father is not excluded from paternity, a second calculation and a test of the putative father is required. This is *the*

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by a DSIR study: F J Hamilton, S J Cordiner and G K Chambers "A Survey of Band Sharing in the New Zealand Population with Multi-locus probe 33.15" (September 1990, DSIR, Report No Cd). 0.26 is the most conservative figure in use. DNA Diagnostics Ltd use the statistic 0.25 as the band sharing ratio that exists between unrelated people, which is still a highly conservative figure: correspondence with Dr P Stapleton, above n 44.

82 Assuming independence: see section 3.4, below p 28.

83 Although it does assume that the probability of a match always = 1.

84 J M Faed and A E Knight, above n 54, 1

85 J M Faed and A E Knight, above n 54, 8

chance or probability for paternity of that particular man. The common alternative ways of presenting this result are either as:

i) an odds ratio (eg. 1 in 83),
ii) a paternity index (eg. 83),
or iii) a probability or percentage chance for paternity (eg. 98.8 %[86])

While the probability for paternity is, at the moment, the most common mode of expression, there is a growing body of opinion which supports the giving of DNA and blood test evidence in parentage cases in the form of odds ratios.[87]

A third statistic which is sometimes quoted is *the chance for a random male to father the child in question.* Concern has been expressed by some members of the medical profession[88] that this is not a reliable indicator of the proportion of all males who could father a child with the same test results.

3.3 Population Data

DNA studies have often established that the frequency of particular bands being shared in the population varies between ethnic groups. This is particularly true of the highly sensitive single locus probe bands.[89] Some alleles are much more common in some groups than in

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86 If the likelihood ratio is assigned the value x, this percentage is calculated:

$$\frac{x}{x+1} \times \frac{100}{1} \quad \text{e.g.} \quad \frac{83}{84} = 98.8\%$$

87 See section 5.5, below p40, where the reasons for this preference are discussed.

88 J M Faed and A E Knight, above n 54, 8. The main reason for concern is that the stastistic effectively combines these 2 pieces of evidence:
(a) The chance that a random male will not be excluded from paternity of the child born to the mother in question, and
(b) The chance that a non-excluded man could have produced this particular child, out of all the possible children he could have fathered with the mother in question.

89 The overall band sharing frequency has been found to vary from 0.17 to 0.24 amongst New Zealand's major ethnic groups (Caucasians, Maoris, Pacific Islanders and Asians), although this variation was not found to be statistically significant:

others. How might this variation affect the DNA statistics ? If a suspect is compared against their ethnic group, the likelihood ratio will probably decrease, because the denominator is likely to be higher if the bands are more common.

Small sub-populations which have a degree of interbreeding will also exhibit certain bands which are more common than in the general population, making general data inapplicable. Differences in band frequency have even been found to exist between two large American cities.[90] In reality, most sub-populations would contain a very low degree of interbreeding, because it is well known that "people do not pick their partners randomly."[91] However, the statistical impact of this is not likely to be serious, if noticeable at all.[92] If anything, the results should err on the side of conservativeness if general population data is used.

The New Zealand DNA testing laboratories appear to be strongly aware of the need to work only with adequate and relevant databases. For example the DSIR, in collaboration with DNA Diagnostics, have spent considerable time in producing a database for the statistical analysis of single locus probes. Information has had to be gathered for each racial group. This should be completed in the not too distant future, allowing much more reliance to be placed on single locus probe analysis here.[93]

Another hurdle in the collection of appropriate data is the expense and difficulty of large scale population studies. There is always a possibility that the data put forward in DNA evidence may be based on small samples, or it could be "borrowed" from other ill-fitted groups. Just what the size of an adequate population sample is, has no simple

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F J Hamilton, S J Cordiner and G K Chambers, above n 81. Hence the 0.26^{x} formula for multi-locus probes is said not to be affected by race.

90 W C Thompson and S Ford, above n 61, 25, comparing Miami and Houston.

91 C Joyce, above n 69, 10

92 C Joyce, above n 69, canvasses the debate about whether arguments over statistics amount to "hairsplitting".

93 It has, however, been suggested by DNA Diagnostics, above n 44, that:

> Because the population of New Zealand is small, and some groups represented here are indeed quite tiny, it may not be possible to establish an entirely satisfactory database for single locus probes.

answer. Many experiments are based on samples smaller than 100 people,[94] but what is really important must be the number of comparisons that are made within that sample.[95]

Strictly speaking, whatever method is used for declaring a match in an individual case, should be precisely the same as that used in the population data being applied. In the same vein, it is possible to object to DNA evidence if ethnic group data has been collected on the basis of *potitical and social* ethnic definition, but the reason the data is applicable to the circumstances is because of an *eyewitness* account of the perpetrator's appearance. These are further problems that create weaknesses in population data. Having pointed them out, heed should be paid to this comment:[96]

> Even though the perfect survey is never available, the scientist should not despair. It is better to have some data available than none at all, and by using good judgment it will often be possible to modify existing survey data to compensate for the case variables.

3.4 The Product Rule

The chance of a coincidental match on one test can be combined by a simple multiplication with the results of another, to produce an overall statistic, if the bands are *independent*. A clear example of the use of this rule, called the product rule, is the basis of the calculation of a single likelihood statistic for multi-locus DNA results. The bands are independent if:[97]

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94 The study by F J Hamilton, S J Cordiner and G K Chambers, for example, above n 81, had a sample size of 118 people.

95 Hence quite small samples might be sufficient. Note that the study by A J Jeffreys, V Wilson and S L Thein, above n 15, (which pioneered DNA profiling), was based on a sample of only 20 British Caucasians. That would probably be an adequate survey if they were exhaustively cross-checked, but apparently each sample was only compared to one or two others: see W C Thompson and S Ford, above n 9, 83.

96 J S Buckleton, I W Evett and K A J Walsh, above n 78, 7

97 W C Thompson and S Ford, above n 9, 81

the probability of a match on each band is unaffected by the occurrence of a match on any other band.

The application of the product rule is, however, not valid if the alleles are not independent because of some correlation between their existence. The same considerations about interbreeding and randomly mixed populations apply here.[98] In the absence of data to the contrary, independence of the probability of a band matching has generally been assumed to exist. This has been called into serious question by some commentators,[99] although more experiments verifying the independence of the alleles detected by specific probes are being conducted. Again, it can be argued that the statistical impact of some very low, unknown correlation between DNA bands is not likely to be serious.

4. The Impact of DNA Profiling in the Law

4.1 Applications

(a) Criminal

The impact that DNA evidence may have in serious criminal cases is indisputable. The potential ability of this highly sensitive new technology to positively link a suspect to a crime by body samples, has already been mentioned. In addition, DNA profiling offers some new possibilities in forensic applications. The tests are especially useful in rape and sexual abuse cases, since semen from the victim's swab can be separated out to produce an individual profile. DNA profiling can be used in relation to serial offenders and multiple crime scenes, enabling police to determine the number and identity of different perpetrators involved. The technique can also be used to identify the remains of victims. And most importantly, DNA can exculpate wrongly accused suspects.

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98 The condition of independence and random mixing is called *Hardy-Weinberg equilibrium.*

99 W C Thompson and S Ford, above n 9, 83 and J J Barr, above n 12, 505.

Another advantage of DNA profiling in forensic work is the range of body samples that can be tested, depending on the nature of the investigation. Potential samples include whole blood, dried blood, semen stains, skin, hair roots, bone marrow, dental pulp, amniotic fluid, a foetus, and vaginal swabs. With less frequency, DNA tests may be done on urine, saliva and sweat.[100]

Further, DNA profiling can be performed on forensic samples that are somewhat dried or aged, whereas traditional blood typing cannot. The structure of DNA in a cell nucleus is more robust than the cell itself. Successful tests have been known to be performed on samples up to four years old.[101] Attempts have even been made to test DNA samples extracted from an Egyptian mummy[102] and from remains believed to be those of an infamous Nazi doctor.[103]

(b) Parentage

DNA technology can be used to resolve a wide number of disputes about whether two people are related, since an individual's DNA is inherited, half being contributed by each parent. The technique could be applied as unequivocally strong evidence of a biological relationship in paternity[104] and maternity disputes, immigration, or inheritance claims. Most issues of parentage will arise in the context of civil claims, although criminal offences in matters of immigration or incest might also require a family relationship to be established.

Many people believe that the impact of DNA profiling in parentage disputes will be so great as to render conventional bloodgroup testing obselete. Needless to say, commercial laboratories who do not offer conventional tests, such as DNA Diagnostics and Genetic Technologies,

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100 J J Barr, above n 12, 513. The tests cannot usually be done on feces, hair with no roots, red blood cells, or dead skin.

101 C M Tande, above n 19, 481, and P Gill, A J Jeffreys and D J Werrett "Forensic application of DNA 'fingerprints'" (1985) 318 Nature 577. The latter is a study of the effects of aged and degraded samples.

102 Noted by J J D Greenwood and R M White, above n 19, 147.

103 Noted by B Selinger and E Magnusson, above n 23, 8.

104 Whether for the purposes of maintenance, Social Welfare benefits or paternity orders (section 47 Family Proceedings Act 1980).

advocate that blood tests are unnecessary and of limited value because of the accuracy of DNA analysis. On the other hand, Blood Transfusion Centres who continue to conduct conventional tests as well, recommend that DNA profiling should only be used in conjunction with other tests, at least in the early stages while there is so much unresolved about DNA analysis. This is in accordance with a recommendation from the International Society for Forensic Haemogenetics.[105]

4.2 Limitations

A major limitation of DNA profiling is that it is very labour intensive, and needs "both meticulous expertise and much experience."[106] The testing process is neither quick nor cheap, taking more than two weeks to complete in many instances. Hence for forensic investigations, DNA testing will usually be restricted to cases involving serious assaults, including murder and sexual offences. In paternity disputes, legal aid should be available to cover the costs of testing in appropriate cases.[107]

Although the tests are generally conducted by highly skilled scientists and technicians, no scientific procedure is immune from error, as will be seen below in the famous *Castro* case. As a specific example, the "continuity" of samples might be broken because of a mix-up caused by accidental mislabelling. Instruments and reagents could be contaminated. Enzyme digestion of the DNA may be incomplete, or distortions in the gel may arise. Experimental

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[105] This area of debate is further discussed by B M Zimmerman "DNA Parentage Testing - The New Zealand Context" (1990) submitted for LLB(Honours) at Victoria University of Wellington, 14, and in Comment "DNA - the debate goes on: test techniques under scrutiny" (1990) 341 Law Talk 21. In the latter it is noted that:

> For some time now the Family Law Committee of the New Zealand Law Society has been monitoring developments relating to DNA testing and the use of such tests in resolving paternity disputes.

Also see "Lawyers warned - DNA tests not infallible as proof of paternity" *Otago Daily Times*, Dunedin, 23 October 1990.

[106] B E Dodd "DNA Fingerprinting in Matters of Family and Crime" (1985) 318 Nature 506

[107] See B M Zimmerman, above n 105, 23.

conditions such as time, temperature or chemical concentration might be incorrect.[108]

Most laboratories have their own protocols and quality controls to alleviate the chance of error. However there are no universal guidelines, partly because of the number of different techniques and types of probes currently used. Laboratories tend to formulate standards in association with others that use similar procedures.

The techniques are usually subject to patent, which has created a "virtual monopoly over testing procedures".[109] The strongest competition has been amongst the major commercial testing laboratories in the United States, arousing concern that a profit motive may interfere with the integrity of their testing. This has led to a suggestion by two American authors that:[110]

> [t]he laboratories, in the rush to meet the market for forensic tests, may have made too many simplifying assumptions and cut too many corners.

In the writer's view, there are probably two reasons why a similar problem has not developed in New Zealand. One is that, at present, this country's police forensic testing is all performed by the DSIR, unlike the position in Australia and the United States, where private laboratories do a significant proportion of forensic DNA testing. In New Zealand none of the private laboratories, except for Genetic Technologies based in New South Wales, have experience or background in forensic testing.

The second reason is that the commercial marketing of DNA profiling techniques is relatively new in New Zealand. DNA evidence is only just beginning to be presented and challenged in our courts. It may be that in a few years time the competition between the private

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108 K Reed "Potential Sources of Artifacts and errors in generating a 'DNA profile'" in *DNA and Criminal Justice: Conference Proceedings*, above n 23, 103, contains an extensive list of possible errors in the testing procedure.

109 A Hall "DNA Fingerprints - Black Box or Black Hole?" [1990] 140 New LJ 203, 204.

110 W C Thompson and S Ford, above n 61, 25

laboratories for civil dispute testing here will be just as fierce as it has been overseas.[111]

It will have become clear that a critical limitation in criminal investigation work is the quantity, age and quality of the sample obtained from the crime scene or victim. In most cases repeat tests cannot be done, whereas they can in most civil claims. Much ultimately depends upon the when and how the samples are collected, and the subsequent storage conditions. Of the victims who do report sexual offences, many do so too late for a sample to be obtained. These sorts of factors have caused at least one author to say that the greatest application of DNA testing is in relation to paternity determinations, while in the criminal arena it will have a more limited impact.[112]

The same author points out that a further limiting factor in criminal testing is where there is no real doubt about the identity of the suspect[113]. The real utility of DNA profiling can be overstated in allegation of sexual assault for example, because the existence or non-existence of consent is often the critical evidential issue. DNA technology can, of course, offer nothing to resolve this question.

Another problem likely to be encountered with DNA evidence, although not connected to the actual testing procedures, is the issue of consent to body sample tests and the power of authorities to take samples.[114]

III. DNA EVIDENCE IN COURT

While the legal system has had considerable experience dealing with scientific evidence, DNA testing is especially challenging because of its unusual complexity and the difficult statistical issues it raises. Since obtaining a DNA profile and interpreting the results demands a high degree of technical expertise, it is clearly within the realm of

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111 It should be noted that, perhaps not insignificantly, the New Zealand private laboratories offering DNA testing services embarked on advertising campaigns soon after the technology was available.

112 I Freckleton, above n 2, 27-28.

113 I Freckleton, above n 2, 27

114 See above n 11

expert evidence when tendered as proof in the law. The next few sections briefly consider the general principles which govern expert testimony.

5.1 General Admissibility of Expert Evidence

Expert witnesses represent an exception to the rule that witnesses are not permitted to express an opinion. They are entitled, and indeed expected, to draw inferences from their own observations where judges and jurors are not equipped to draw the proper conclusions themselves. The facts upon which an expert's opinion is based must also be admitted in evidence.

The boundaries of expert evidence extend to take in all matters where a tribunal of fact requires assistance to resolve specialised, scientific or technical issues that are beyond the experience and knowledge of laypeople. Testimony on matters within "ordinary human experience"[115] is inadmissible since it usurps the function of the judge or jury.

As a general rule, no witness can state their opinion on the ultimate issues to be determined in a case. The rationale is that if an expert could express an opinion on the very question which the fact finder is to decide, that would "[tend] to shift responsibility from the bench or the jury to the witness box".[116] This rule has been the subject of criticism, and in some jurisdictions it has been eroded or reformulated.[117] *Cross* supports the "better and simpler solution" of

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115 *R* v *Turner* [1975] 1 AllER 70, 74 (CA) per Lawton LJ. In this case the evidence of a psychologist regarding the accused's personality was held to be inadmissible because the information was within the knowledge of ordinary human experience.

116 *Joseph Crosfield & Sons* v *Technichemical Laboratories Ltd* (1913) 29 TLR 378, 379

117 Some Australian cases are cited in D L Mathieson *Cross on Evidence* (Butterworths, Wellington, 1989, 4NZed) at para 15.16, where the rule has been taken to exclude opinion only on the application of an "essentially legal standard". While acknowledging academic support for this approach, the author of that text does not find it workable.

accepting opinion wherever it is helpful to the court to do so, irrespective of the status of the issues to which it relates.[118]

Expert witnesses must qualify themselves to the court prior to the admission of opinion evidence. The assessment of their qualification and competence is a question for the trial judge. Experts may give evidence that is partly based upon the writings and research of others. Portions of such works might be put to him or her in cross-examination, and in this way published literature can be used as evidence in the case.[119] It is unclear whether the judge or jury are permitted to form opinions on the basis of their own research of authoritative works on a subject.[120]

In summary, it might be useful to consider all expert testimony as subject to two main constraints. One is relevancy, and the other is that it must be of some assistance to the trier of fact.

5.2 Novel Scientific Evidence

A special rule governing the admissibility of novel scientific evidence exists in a majority of United States jurisdictions. It has become known as the *Frye* test, after the case from which it originated in 1923.[121] Under this test expert evidence will only be admissible if

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118 *Cross on Evidence*, idem. This approach has been implemented by some English case law and statutory provisions. It is also the approach of the US Federal Rules: see below n 123.

119 For example in *R* v *Abadom* [1983] 1 AllER 364 (CA) (Home Office statistical records on which the expert's opinion was based were held to be admissible).

120 Section 42 of the Evidence Act 1908 provides:

> All Courts and person acting judicially may, in matters of public history, literature, science, or art, refer, for the purposes of evidence, to such published books, maps or charts as such Courts or persons consider to be of authority on the subjects to which they respectively relate.

But there are several authorities that suggest it should be limited to literature adduced at the trial: see *Cross on Evidence*, above n 117, para 15.09 (fn6).

121 *Frye* v *United States* 293 F1013 (DCCirc 1923), where the Columbia District Court of Appeals rejected the defendant's attempt to introduce evidence of a lie-detector test. The Court also made this comment:

> Just when a scientific principle crossed the line between the experimental and demonstrable stages is difficult to define. Sometimes in this twilight zone the evidential force of the principle must be recognised.

there is "general acceptance" of the technique in the relevant scientific community. If there is doubt whether a particular technique meets this standard, there will be a pre-trial hearing, known as a *Frye* hearing, to determine the question.

While the *Frye* decision attempts to ensure the reliability of new techniques, many Unites States courts have found it vague and difficult to apply.[122] A significant minority of states have modified the test, or rejected it in favour of traditional rules governing relevancy and expert testimony. Under these rules, the probative value of evidence from an emerging research area would be weighed against its prejudicial effect.[123]

The *Frye* test has not been considered at such lengths in other countries. For the first time in New Zealand, McMullin J referred to such a rule in the 1987 Court of Appeal decision of *R* v *B(an accused)*. He said:[124]

> As a *precondition* of admissibility the subject-matter to which the expert opinion relates must be a *sufficiently recognised branch of science* at the time the evidence is given ...Whether the area on which the witness seeks to express an opinion is properly the subject of expert opinion ... will be for the Court to decide in the light of the knowledge prevailing at the time ...

The Judge does not mention *Frye* or other authorities on this point. With respect, His Honour seems to have simply presumed that the

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122 The status of the *Frye* test in different US jurisdictions is fully surveyed in M McMormick "Scientific Evidence: Defining a New Approach to Admissibility" [1982] 67 Iowa LR 879, 882, and in J C Hoeffel, above n 19, 496. There is further discussion of the justifications and criticisms of the *Frye* test in W C Thompson and S Ford, above n 9, and J J Barr, above n 12, 517.

123 The US Federal Rules of Evidence, enacted in 1975, have two main sections relevent to scientific evidence. Rules 401-403 define relevant evidence, state that all relevant evidence is generally admissible, and that relevant evidence may be excluded on the grounds of prejudice, confusion or waste of time. Rules 702-704 define and discuss the ambit of expert tesimony and opinion. See L Beeler and W R Wiebe, above n 19, 934.

124 [1987] 1 NZLR 362, 367 (CA) [own emphasis]. The case considered the admissibility of a child psychologist's evidence in a sexual abuse case.

"general acceptance" test applies in New Zealand, without any consideration of the merits of such a rule.

Strictly speaking, McMullin J's statement is obiter, since the Court did not deny that the psychologist's discipline could properly be the subject of expert testimony.[125] However, McMullin J went on to confirm this principle as law two years later in the Court of Appeal decision of *R* v *Accused*.[126] He referred to it as a feature which was common to all the judgments in *R* v *B*[127]. In New Zealand then, there exists an equivalent of the *Frye* test, but it has never been applied in any case.

In Australia, a principle virtually identical to the Frye standard was adopted in *R* v *Lewis*[128], a decision of the Northern Territory Court of Criminal Appeal. The Court held that the *Frye* test had not actually become law in Australia, but it produced a useful guideline for determining the admissibility of novel forensic evidence. Two dentists had been called by the Crown to testify to a method of identifying a rape suspect by matching bite marks. The evidence was deemed inadmissible because another recent case[129] had found no consensus amongst scientists as to the reliability of the technique.

5.3 Admissibility and Weight

In this country it would certainly be possible to hold a pre-trial hearing, or voir dire, on the admissibility of DNA tests in a particular case. The emphasis of such a hearing might be the *Frye* standard for novel scientific evidence, although considering that DNA technology is frequently accepted as evidence in other jurisdictions, it is doubtful that the *Frye* test alone will keep such evidence out of court.

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125 Idem

126 [1989] 1 NZLR 714, 720 (CA). This case also considered the admissibility of a child psychologist's evidence in an allegation of sexual abuse.

127 With respect, however, it appears that McMullin J was the only Judge to mention the principle in the earlier case.

128 (1987) 29 A Crim R 267 (CCrApp, Nth Terr)

129 *R* v *Carroll* (1985) 19 A Crim R 410 (CCrApp, Qld)

Alternatively, the pre-trial hearing could focus on the general requirements of expert testimony. Given the damning impression that DNA evidence can create, it may also be important to determine whether the probative value of the evidence is outweighed by its prejudicial effect against a defendant, *before* it is received by the tribunal of fact. This judicial discretion becomes of major significance in cases involving scientific testimony which is expressed in statistical terms. This may be because of a court's inability to properly assess the evidence, or perhaps it is because of the way the evidence is presented.

There has been some debate about which of the following matters should go to weight of the evidence and which to admissibility:[130] the criteria for identifying matches; the statistical probabilities; the adequacy of the population studies; laboratory procedures and quality control; suggestions of laboratory error; and the reasons that the suspect was selected for testing. It is submitted that all of these matters should normally be put to the tribunal of fact to assess. Only in cases where the evidence is very likely to mislead or confuse the jury, should it be held inadmissible.

Note that in paternity disputes, the evidentiary requirements are much more relaxed than the tenor of the above discussion. A Court may receive any evidence it thinks fit, whether it is technically admissible or not.[131]

Expert testimony, like any other evidence, must of course be interpreted in the context of the totality of evidence in the case. This important principle can be easily overlooked when faced with technical expert evidence. There is no magical size of the likelihood ratio which will determine guilt or amount to proof. It follows that the

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[130] See W C Thompson and S Ford, above n 9, 103, and L Beeler and W R Wiebe, above n 19, 938. The first of these articles discusses the American case of *Wesley*, above n 18, in which arguments were made about whether the adequacy of Lifecodes' laboratory procedures and population studies should go to the weight of the evidence or its admissibilty. The Court found it unnecessary to resolve the issue.

[131] Section 164 Family Proceedings Act 1980

likelihood ratio, or an equivalent percentage, cannot be equated with the burden of proof.[132]

5.4 Judges, Lawyers and Juries

It has been said that lay jurors attach "an aura of special reliability and trustworthiness" to expert scientific witnesses, and a "mystic infallibility" to their testimony.[133] They may be overly influenced by laboratory tests, scientific jargon and witnesses with impressive credentials. As a result, it is widely believed that jurors tend to accept highly technical evidence without proper scrutiny. They might also fail to properly combine the statistical evidence with all the other unquantified evidence in the case.[134] A contrary view has been expressed that jurors, and probably also judges, have a greater capacity to understand and weigh scientific evidence than they are sometimes given credit for[135], but many New Zealand scientists involved have serious doubts about the comprehension of DNA evidence by laypeople.

There is a specific issue whether the DNA profiles should be produced in evidence and shown to a jury. Apart from the general prejudicial effect objection, another possible argument against this practice is that jurors might attempt to read the evidence themselves by matching bands, while they do not have the experience required. On the other hand, the autorads might help them to understand the

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[132] It should be remembered that the standard of proof in civil cases (including the Family Court) is far less stringent than the criminal evidentiary standard of beyond reasonable doubt. Normally parentage cases will need to be satisfied on the balance of probabilities, but in paternity applications, due weight must be given to the gravity of the allegation: *Hall* v *Vail* [1972] NZLR 95 (CA).

[133] C L Williams "DNA Fingerprinting: A Revolutionary Technique in Forensic Science and its probable effects on Criminal Evidentiary Law" (1987) 37 Drake LR 1, 11 (citations omitted). In a recent New Zealand Court of Appeal decision involving forensic evidence, *R* v *Tihi* [1990] 1 NZLR 540 (CA) (a scientist had performed some tests to detect blood), the Court said (at p548):

> It is true that juries pay particular regard to scientific evidence and therefore it must be carefully presented so that it is an accurate account of the result... and fairly presented. It must give a complete picture...

[134] The logic of Bayes theorem provides a useful model for combining evidence, but of course most people do not strictly organise or analyse their thought processes in those terms.

[135] Quoted by C L Williams, above n 133.

nature of the evidence. In a case where there are conflicting views about the matching of DNA bands, it would no doubt be useful for a jury to see the profiles, as long as the appropriate jury warnings are given. If band matching is not in issue, there seems to be no reason why the autorads should be produced in evidence.

An interesting theoretical question arises about how much of the complex science behind DNA profiling the legal profession need to understand. Most lawyers are hardly qualified to properly assess and challenge DNA evidence. Yet the adversary structure of our legal system requires that the lawyers and judges involved gain a working knowledge of the science in order to conduct a trial. In particular, counsel need a clear appreciation of the contentious points for them to cross-examine an expert. This is especially true for defence counsel in criminal cases who are unable to produce their own expert witnesses. None of the relevant literature can suggest any shortcuts to a detailed preparation by lawyers on the technical and scientific aspects.[136]

It is probably fair to say that lawyers' preparation and briefing in a DNA case is now in the process of shifting focus. Since DNA profiling was first tendered as evidence a few years ago, there has been a tendency to concentrate on challenging the testing procedures and band matching involved. However, recently many people are beginning to realise that statistical interpretations and population genetics leave just as much room for scrutiny, if not more.

5.5 Statistics in Court

The earlier discussion on statistics in the interpretation of DNA tests revealed more than one way of presenting the results as evidence. The outcome of a DNA analysis, expressed as the chance of a coincidental match with "someone else", could possibly be given in the form of likelihood ratios, probabilities, or indices. What these statistics effectively do is quantify how likely some alternative hypothesis (usually that the DNA profile could have come from a

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136 J H Phillips and J K Bowen, above n 13, contains two introductory chapters (chs 10 and 11) on the giving of scientific expert evidence in court, focussing on preparation and cross-examination.

randomly selected member of the population) is. It was noted earlier that the likelihood ratio is now considered to be a very useful way of analysing and presenting DNA evidence, particularly in forensic investigation work.

Paternity test results have traditionally been conveyed as probabilities of parentage, not odds or likelihood ratios, just as they are for conventional blood tests.[137] At least one private laboratory in NZ denounces this practice and now presents evidence as an odds ratio.[138] There are also commentators who support this practice with statements such as, "the need for a ratio rather than a single probability cannot be over-emphasised"[139], and "in paternity cases experts have long been giving evidence in a misleading form"[140].

A number of reasons can be given why the presentation of DNA evidence as probabilities should be discouraged. Firstly, it is said that the percentage chance for paternity, along with the paternity index, is "generally not well understood by those who have not had a training in statistics"[141]. By contrast, "betting odds" provides a much simpler expression. An additional reason which specifically pertains to the very accurate DNA tests is comprehension of the true significance and magnitude of the results. For example the difference between 99.2% and 99.92% doesn't appear to be very significant.[142] In fact these two figures expressed as likelihood ratios are 1 in 124 and 1 in 1249, which much more readily shows that the second statistic is ten times more powerful that the first.

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137 For example, evidence was given in this form in the New Zealand paternity cases of *Hirini* v *Kirkwood* [1990] 5 NZFLR 521 (FC)(Inglis J) (blood tests, and a hypothetical DNA paternity test was also considered by the Court(p524)), and *Byers* v *Nicholls* (1988) 4 NZFLR 545 (HC)(Tompkins J) (blood tests).

138 J M Faed and A E Knight, above n 54, 8

139 B Selinger and E Magnusson, above n 23, 3

140 B Robertson and A Vignaux, above n 74

141 J M Faed and A E Knight, above n 54, 8

142 Although take note that a rehearing was granted in the paternity case of *Hirini* v *Kirkwood*, above n 137, when the expert witness provided a further report and explanation changing the probability of paternity based on blood and tissue tests from 98% to 99.8%.

Another important motivation is that with probabilities there is more of a tendency not to carefully formulate the appropriate alternative hypothesis. Expression as a probability no doubt also increases the tendency to equate the scientific evidence with the burden of proof. If the evidence is instead presented as a likelihood ratio, this may help the court to properly understand and assess the evidence, if not the expert as well. The evidence would be in a form which gives the tribunal of fact better guidance as to how to combine the DNA statistics with the other evidence in the case.

A further objection can be made based on mathematical principle. That is, probability calculations assume a *prior* assessment of the probability of the evidence, but those performing the calculations rarely have any other information about the case.[143] In comparison, the *prior* in Bayesian analysis is a separate component from the likelihood ratio of a particular piece of evidence given by the expert.

Evett[144] and some other statisticians perceive a problem in presenting any statistical evidence in a courtroom, where most people will have little or no formal statistical knowledge. They believe that numerical odds and probabilities do not mean much to lawyers and jurors. The solution suggested by Evett[145] is to assign the following verbal scale to the likelihood ratio.

LR in the range	Evidence strength
1 to 32	Weak
32 to 100	Fair
100 to 320	Good
320 to 1000	Strong
over 1000	Very strong

Another suggestion is[146]:

1 to 10	The evidence slightly supports C
10 to 100	The evidence supports C

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143 Many laboratories simply assume a prior of 0.5 (ie. no more likely than not).

144 I W Evett "Bayes and Forensic Science: Pragmatism, Compromise or Heresy?" (Poster presented at the Valencia Conference, April 1991), and I W Evett and J Buckleton "Some Aspects of the Bayesian approach to evidence evaluation" (Home Office, Unoted Kingdom, and DSIR, Auckland), 10.

145 I W Evett, ibid, 3

146 I W Evett and J Buckleton, above n 144, 11

100 to 1000	The evidence strongly supports C
1000 and above	The evidence very strongly supports C

A further scale used by one of the private New Zealand parentage testing laboratories is:[147]

1 to 49	Moderate chance for paternity
50 to 49	High chance for paternity
over 500	Very high chance for paternity

In the writer's view, those scales used alone are arbitrary and will only serve to obscure the evidence. Furthermore, Evett concedes to a problem of "running out of ideas" to find verbal equivalents for the very high likelihood ratios (above 10,000), which are commonly produced by DNA tests. However, these difficulties are virtually alleviated if the language equivalents are quoted in addition to the numerical statistics. Indeed they may help to put some "perspective" on the values. There can be no real objections to the presentation of both to a court, which is the current practice of the DSIR, as long as the language equivalent is stated to be the expert's opinion.

Note that the verbal scales fall short of expressing an opinion on the ultimate issue to be determined. In parentage testing this will be less obvious than in criminal cases, since the ultimate issue is virtually the same as the question that the DNA results support. But the results must still be combined with all the other evidence in the case. It would clearly be inappropriate, and perhaps misleading, for any DNA expert to say that the evidence has been established "beyond all reasonable doubt." That is the business of the fact finder. Similarly, a parentage testing laboratory is not in a position to express an opinion about the likelihood or probability that "this person is the father of the child."[148]

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147 J M Faed and A E Knight, above n 54, 8

148 In this regard it is therefore inappropriate for laboratories to express conclusions in their standard forms for presenting results such as those contained in Appendix A (DNA Diagnostics) and Appendix B (Otago Regional Blood Transfusion Service). Also see B Robertson and A Vignaux, above n 74.

6.6 The Role of The Expert Witness

The view is held by many that the adversary system is not well suited to the giving of expert scientific evidence. Some forensic experts have reported feeling that they were not able to present a true picture of their evidence because of the restrictive and interruptive question and answer procedure in a courtroom. In a worst case scenario, such distortion might lead to important forensic evidence not being disclosed.[149] In common law jurisdictions like New Zealand, expert witnesses are employed and renumerated by one of the adversary parties. Despite the fact that most experts subscribe to the ethic that they give evidence as an impartial witness of the court rather than on behalf of a particular party[150], perceived partisanship is common.[151] Overall, the criticism is made that scientific "experts" simply become experts at being adversaries.

It is a point of debate whether a system of neutral, court-appointed scientific experts would work more effectively. This is the practice in European countries like France and Norway. While there is considerable support for neutral "assessors" to be selected from a panel of approved experts,[152] others believe that such a system would not solve the present alleged flaws, and may even create some problems of its own. The adversarial process, it is claimed, provides the best built-in check against bias and full disclosure.[153]

While admitting that there are difficulties with presenting technical expert evidence in New Zealand's existing legal structure, it is submitted that the system could be improved if appropriate pre-trial disclosure and consultation ocurred in every case. The nature of DNA evidence is such that we need "to remove as far as possible the element

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149 See the specific examples in T Sargant and P Hill, above n 62, 24

150 J H Phillips and J K Bowen, above n 13, 83

151 The perception will not always be illusory. There will inevitably be some witnesses whose opinions are influenced by "bias and distortion, conscious or otherwise." (J H Phillips and J K Bowen, above n 13, 83).

152 See generally J R Spencer "The Neutral Expert: an implausible bogey" [1991] Crim LR 106, and A Kenny "The Expert Witness in Court" [1983] 99 LQR 197.

153 See M N Howard "The Neutral Expert: a plausible threat to justice" [1991] Crim LR 98 (to which J R Spencer's article, idem, is a reply).

of surprise."[154] Unfortunately consultation beyond an exchange of experts' reports is uncommon.[155] One author suggests that the expert's disclosure is largely controlled by his or her knowledge of the relevant facts of the case, since otherwise they do not know what crucial issues their testimony has to address.[156] Most facts in a case will not be relevant to the DNA expert's evidence, however some will be. In particular, the scientist needs to be informed of any information which will restrict the population database to be compared, before they interpret the DNA results.

IV. CASES

6. New Zealand

6.1 *R v Pengelly*

High Court [157]

In April 1990 Michael Pengelly, aged 18, was found guilty of murdering 77 year-old Mrs Birch of Ranui in her home on the evening of 8 May 1989. The case against Pengelly was that he went to Mrs Birch's house, removed louvre windows to get in and cut his finger, leaving a number of bloodstains inside and outside the house. He went to the bedroom, intending to rape Mrs Birch, but instead he stabbed her several times.

The central issue in the case concerned the identity of the murderer. Four expert witnesses were called by the Crown: a pathologist, a fingerprint technician, a conventional bloodtyping scientist, and a DNA profiling expert. Counsel for the defence admitted that the fingerprints on the louvres were those of the accused, but he

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154 T Sargant and P Hill, above n 62, 27

155 Note that defence counsel have ready access to DSIR examinations in criminal cases (governed by Appendix II of *Rules of Professional Conduct for Barristers and Solicitors* New Zealand Law Society, 1 March 1990).

156 D J Gee "The Expert Witness in the Criminal Trial" [1987] Crim LR 307, 310

157 Above n 3. This material is drawn from the transcript of Thorp J's summing up, the transcript of the DNA expert's evidence (Dr Margaret Lawton, DSIR), and a newspaper report the day after the jury gave its verdict: "Youth found guilty in DNA case" *Evening Post*, 7 April 1990.

suggested they were put there some weeks earlier during a "drinking binge".

There was a short pre-trial hearing[158] about the admissibility of a blood sample taken from the accused and statements made by him, based on the way the police obtained them. A pre-trial challenge was not made to the admissibility of the actual DNA results being given at the trial, even though this is the first time DNA evidence has been contested in a New Zealand court.

The DNA expert was given blood samples from the deceased, the accused, and six samples from the crime scene, after the blood analyst had finished testing them. Multilocus probes were used to obtain DNA profiles.[159] Only two out of the six crime scene stains produced profiles that were clear enough to read: a stain from the kitchen floor and a stain from a net curtain. One of the reasons for this could have been the small quantities of DNA obtained from some samples.[160] The witness was thoroughly interrogated at the trial about the procedures and controls of the DSIR laboratory. It is perhaps interesting to note that the lengthy cross-examination of this witness by defence counsel concentrated solely on the DNA testing process, and the only questions about population data and statistical analysis were asked by the Court.

On comparing Pengelly's sample with the two crime stains, Dr Lawton said in evidence:[161]

> I find that the results I obtained were at least 12450 times[162] more likely to have occurred if the blood had originated from Pengelly than if it had originated from someone else... it could also be said that one in 12450 people would have the same profile

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158 Above n 3

159 There was an attempt at re-probing with a single locus probe, although it was unsucessful.

160 The DSIR expert testified that she had approximately between one third and two thirds of a microgram of DNA (after purification), whereas it was preferable to have in the region of at least one microgram of DNA: trial transcript p179.

161 Trial transcript p170. She later clarified that "someone else" meant a person selected at random from the population.

162 This number was later said in evidence (transcript p187) to be obtained using the 0.26^x formula, where x=7.

> as the DNA from the stains... and that Pengelly was included in that number.

In the writer's opinion, this is a clear and helpful way of describing likelihood ratios in court. The witness then combined this result with the results from the conventional blood grouping tests[163], on the basis that they were independent tests. She obtained likelihood ratios of 1 to 413,300 and 1 to 177,100 for the two different sample stains, and explained them in a way similar to above. Overall, her conclusion was that "the evidence very strongly supports the premise that the two blood stains... came from Pengelly".[164]

Dr Lawton also said in evidence, in answer to a question from the Court:[165]

> It has generally not been accepted by DSIR labs that showing the results of our tests to the jury is a relevant step to take. We feel that in doing that we are asking the jurors to become the experts. Instead our results are open and often subject to peer review by other scientists.

Thorp J in fact admitted the autorads into evidence, his given reason being the possibility that the defence would call a DNA expert witness to give evidence. With respect, this reasoning seems to assume that a challenge to the DNA evidence will revolve around band matching, whereas it could well focus on statistical interpretation. He cautioned the jury about trying to read the profiles as experts.

In summing up, Thorp told the jury that they should:[166]

> sensibly take into account that [DNA profiling] is a novel technique in this country, and that it is appropriate, until its use

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163 Results showed that the blood on the net curtain could have come from 3% of the New Zealand population including Pengelly, and the blood on the kitchen floor had characteristics which could be found in 7% of the population including Pengelly.

164 Trial transcript p171

165 Trial transcript p187

166 Summing up of Thorp J, above n 157, 14

> is more generally understood, to exercise some caution in assessing its results.

His Honour strongly rejected the defence counsel's suggestion to the jury that they should "put to one side" any evidence which they could not interpret. It was for the jury to decide what weight they would give the evidence. And several times throughout the summing up, Thorp J reminded the jury that each piece of evidence had to be interpreted in the context of the whole. The original notice of appeal alleged misdirection by the trial Judge as to the treatment of the DSIR expert evidence, but this was not pursued in the appeal, quite properly in the Court of Appeal's opinion.[167]

Court of Appeal

At the Court of Appeal hearing of *R* v *Pengelly*,[168] before a Full Court, the main grounds of appeal were issues of consent and fairness in the taking of the blood sample from the accused. The appellant's written submissions also advanced the point of appeal "that the evidence of Dr Lawton in respect of exhibit C [the autorad] was not reliable." While this ground was not seriously argued before the Court, a substantial part of the written judgment was devoted to it. The DNA evidence was, in a sense, challenged with the reception of new written evidence by the Court of Appeal.[169]

Exhibit C had been examined after the trial by Dr Geursen, an Auckland molecular geneticist, and by Professor Jeffreys in England, who pioneered the DNA profiling technique. Each asserted in their affidavits that the overall quality of the exhibit was very poor, mainly because of extensive background smearing in all lanes, including the control lanes. They said that the samples from the kitchen floor and the curtain were "not identical" and it could not be said they were "indistinguishable".

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167 Above n 4, 23

168 Above n 4

169 The reasons given for the evidence being admitted were that "this is apparently the first case in which evidence of DNA profiling has been led in a criminal trial in New Zealand", and that the additional evidence was directed to the reliability of the evidence placed before the jury: above, n 4, 14 and 21.

Further, these experts called into question the statistical weight of the evidence and queried the use of the band sharing frequency of 0.26 on these facts. When Pengelly's reference sample was compared with Mrs Birch's reference sample, the experts found a far higher proportion of bands shared between the two than would be expected from the 0.26 figure.[170] This proportion equated to a band sharing ratio of 0.62 and on that basis the "true" likelihood ratios were said to be only 1 in 18 or 1 in 28.

These witnesses were not, of course, comparing either sample with the scene samples, thus no *direct* conclusions can be drawn. It seems their figure of 0.62 was meant to imply that Pengelly and Mrs Birch might have a high band sharing frequency because either:

i) they were related (which they were not known to be),

or ii) the New Zealand population has a *much* higher band sharing frequency than 0.26 (which is unrealistic[171])

or iii) there were so many errors in the testing procedures that 0.62 is the best band-sharing frequency that can be used for the comparison between Pengelly and the crime stains.[172]

After the reports of these two experts, Dr Lawton of the DSIR performed some further tests on a small amount of remaining sample material, as well as re-probing of the original exhibit C. Since the tests had been performed for the High Court trial, there had been an improvement in the sensitivity of the DSIR's testing techniques. Professor Jeffreys then prepared a second report commenting on these results, this time finding that the profiles were "indistinguishable throughout the track."[173] He was also able to

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170 Out of 16 different positions of bands in the two profiles, 10 were shared by both Pengelly and Birch.

171 The conservative 0.26 band sharing frequency has been validated for use in New Zealand by a DSIR study, above n 81, although the study was not available until September 1990.

172 Although compare above n 61.

173 Above n 4, 20

confirm the band sharing statistic as being consistent with 0.26,[174] not 0.62 as he had found previously.

The Court of Appeal received these three reports together, along with a further affidavit from Dr Lawton. Their Honours conclusion was that:[175]

> there is no longer evidence to support the 0.62 factor and Professor Jeffreys' final conclusions are entirely supportive of Dr Lawton ... If the evidence from the further testing had not become available ... there would be no doubt that the value of the DNA evidence ... would be considerably reduced.

As the reliability of the DNA evidence turned out, and since the strength of the Crown case depended on much more that the DNA evidence, it was "abundantly clear that no miscarriage of justice had occurred."[176]

6.2 *Byers v Nicholls*[177]

A brief comment is made here about this High Court decision, which was an appeal from the granting of a paternity order by the Family Court. Although DNA tests were not available at the time, *Byers* v *Nicholls* has some bearing on the principles of interpretation of DNA evidence. A blood test report from the Otago Regional Blood Transfusion Service concluded, in part, that there was a 99% probability for the respondent being the child's father. Tompkins J dismissed the appeal as to the way the Family Court Judge had considered this statistical evidence, in using it to resolve a conflict of other evidence in favour of the applicant.

The High Court Judge commented on the lack of a reported judicial consideration in New Zealand on the significance of the results of a

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174 He found the level of band sharing between the Pengelly and Birch profiles to be approximately 0.35, which in his opinion was consistent within the 0.26 sampling error: above n 4, 20.

175 Above n 4, 22

176 Above n 4, 23

177 Above n 137

blood test, particularly when expressed as a statistical probability. After considering some English paternity cases[178], His Honour stated that:[179]

> [c]are must be taken not to equate a statistical or mathematical probability with probability to be assessed in discharging an onus of proof. Clearly, if the mathematical probability be a high one, then that finding may properly be regarded as of considerable significance in considering the legal probabilities[180] ... But even a high mathematical probability does not translate into forensic certainty...

Tompkins J concluded that the Family Court Judge clearly had this principle in mind, and that he had correctly taken the blood test evidence into account along with all the other evidence. While this decision is careful to apportion appropriate weight to the statistical evidence of paternity, it is submitted that the task of the Court would have been made easier had the evidence been presented as an odds ratio.

6.3 *Loveridge v Adlam*[181]

This is the first reported paternity case in New Zealand to involve DNA profiling evidence. Inglis J of the Family Court considered an application for a paternity order where evidence was given of both blood grouping and DNA tests performed by the Auckland Regional Blood Transfusion Service. On the blood and tissue tests, the analyst concluded that 1 man in 1190 could qualify as a biological father of the child, and that the calculated probability of paternity was 99.9%.[182] The DNA test results were also usefully given in two ways, indicating a

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178 *S* v *S* [1970] 3 AllER 107 (HL), *Re JS(a minor)* [1980] 1 AllER 1061 (CA), *Armitage* v *Nanchen* (1982) 4 FLR 293 (Fam), *Serio* v *Serio* (1983) 4 FLR 756 (CA), and *Turner* v *Blunden* [1986] 2 WLR 491 (Fam).

179 Above n 137, 551

180 A theoretical question can be raised about the relationship or difference, if there is one, between statistical probability and legal probability. See B Robertson and A Vignaux, above n 74.

181 Above n 6

182 Assuming a prior of 0.5

99.5% probability of paternity, and that 5 out of every 1000 men would qualify.

The Judge acknowledged that the DNA evidence was contested here on the basis of the statistical and mathematical process, not the scientific process. The main question to be considered was the weight to be given to the DNA results. An argument was made that "greater" weight should be given to the results because DNA is "reputed to be virtually infallible".[183] Inglis J rejected this, deciding to accord the DNA tests less weight than the blood tests because of a less adequate database, "at least for the present". He states:[184]

> the weight to be attached to the degree of probability derived from it must depend on the breadth and depth of the statistical data base ... it does not take any great leap of insight to deduce that, as in any other statistical exercise, the result of the assessment is in reality no more than an informed guess.

Inglis J also reiterated the principles from *Byers* v *Nicholls* about the danger of translating a high mathematical probability into "forensic certainty", or equating it with the burden of proof. When the scientific evidence was considered in the context of this case as a whole, against the background of inconsistencies in the applicant's oral evidence and another putative father suggested during the hearing, it did not justify a finding of paternity on the balance of probabilities. The Judge went as far as to say that, in general:[185]

> [the statistical likelihood of paternity] is of *no evidential value at all* unless there is a credible foundation in the other evidence in the case which makes it relevant,

although it is difficult to see how this can be correct in principle.

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183 Above n 6, 277

184 Above n 6, 278

185 Above n 6, 281 [own emphasis]

7. United States[186]

7.1 *State of Florida v Andrews*[187]

This was one of the earliest instances of a conviction in the United States using DNA evidence. A DNA profile from the vaginal swab of a rape victim was compared with the suspect's DNA. The expert witness testified that the profiles were a "match", and the chance that the defendant's DNA would be duplicated in another person was about one to 840 million.

The first trial judge held the evidence of the tests admissible, but the prosecution decided to withdraw the statistical evidence. The jury was unable to reach a verdict. This was clearly an erroneous approach, since the statistics are complementary to DNA tests, and are necessary to interpret the results. At the second trial, both the test results and the statistics were admitted. This time the jury convicted Andrews.

7.2 *People v Castro*[188]

DNA evidence was held inadmissible for the first time in *Castro*. It was a pre-trial *Frye* hearing that lasted over 12 weeks. Joseph Castro was charged with the murder of a seven-months pregnant neighbour and her two-year old daughter in the Bronx. The case against him depended almost entirely on DNA testing a small bloodstain found on his watch. Castro claimed that the bloodstain was his own. The tests for the prosecution were carried out by Lifecodes, whose report concluded that the stain "matched" the DNA of one of the victims. It said that the chance of a match occurring at random was 190 million to one.

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186 The number of American cases in which DNA evidence has been admitted is enormous and increasing. For a brief outline of the more important of these, see J J Barr, above n 12, fns 152 and 156.

187 No CR 88/1400 (Orange County Cr Ct Fla 1988), discussed in J H Phillips and J K Bowen, above n 13, 114, and in A P Adema, above n 10, 387.

188 545 NYS 2d (1989) (New York Sup Ct) Sheindlin J

The defence argued that in the rush to use DNA as a forensic tool, the need for rigourous standards had been overlooked. Lander reports some serious deficiencies in Lifecodes' evidence:[189]

- the bands (from several single locus probes) had been visually compared.
- Lifecodes had their own rule (standard deviation) for declaring a match, which was not followed.[190]
- the number of matches was improperly recorded[191]
- some of the probes were contaminated
- there was confusion about the control lane in the autorad
- there were problems with their population database of US Hispanics (including a degree of interbreeding).

The hearing took an unusual twist when the experts for either side held an informal meeting and agreed upon a consensus statement declaring that "the DNA results were not scientifically reliable enough to support that the samples do or do not match."[192] From that point in the trial, the former prosecution witnesses testified for the defence. Not surprisingly, Judge Sheindlin found the evidence before him to be inadmissible because of its unreliability. He did, however, accept the general validity and admissibility of DNA testing provided that certain safeguards were compiled with.

There is an interesting postscript to the case. Quite soon after the admissibility hearing, Castro changed his plea to guilty in return for the minimum sentence. Apparently he also admitted to Sheindlin J

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189 E S Lander "DNA Fingerprinting on trial" (1989) 339 Nature 501. Lander was an expert witness for the defence in *Castro*. Also see J C Hoeffel, above n 19, 476-494, and I Freckleton, above n 2, 34-38.

190 Proponents of the continuous model for assessing the quality of a match would disagree with the rule itself. I W Evett "Interpretation: A Personal Odyssey" (Original Paper, Home Office) says this in commenting on the *Castro* case (at p17):

> the difficulties arose because comparisons which fell just outside an arbitrary threshold were ruled as matches by the expert. The root of the problem of course was not that they fell outside the threshold - but that a threshold was adopted in the first place.

191 Lifecodes recorded three bands in identical positions in all three lanes, but a photograph of the autorad in E S Lander, above n 189, 503, shows that this was clearly erroneous.

192 E S Lander, above n 189, 504

that the blood on his watch was indeed from his victims.[193] The *Castro* case, however, continues to serve as a reminder of the strong need for the scientific community to collectively ensure adequate regulation and standards for DNA testing procedures.

8. Australia

8.1 *R v Elliott* [194]

A voir dire hearing to determine the admissibility of DNA evidence was held before Lindsay Elliott was tried for murder. The only bloodstain came from the jeans that the accused wore on the evening of the stabbing incident. Genetic Technologies conducted the tests using a series of single locus probes, but they only obtained a result for one of the probes because of the small quantity of DNA. Their evidence assessed the odds of somebody other than the victim having the same DNA as that on the jeans by coincidence as "approximately" 210 to one.

All parties in the case agreed that DNA profiling had become an "acceptable scientific technique", however the defence had a number of specific objections to the evidence being admitted. Its reliability was attacked on all the usual aspects of laboratory procedure. Hunt J considered that most of these issues "could be thrashed out without difficulty before the jury".[195]

The relevance of the database used for comparisons was also seriously questioned. This was most appropriate, considering that the population base was taken from a Lifecodes sample of North American Caucasians. To overcome genetic differences between it and the local Australian population which included Aboriginies, the Judge suggested that the jury would have to assess the chances of the blood-source being non-Caucasian and make their own assessment of how

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193 J Phillips "A View From the Bench" in *DNA and Criminal Justice: Conference Proceedings*, above n 23, 25

194 unrep (6/4/90) Sup Ct NSW (Crim Div), Armidale, 70154/89, Hunt J

195 Ibid, 18

the "odds should be reduced accordingly".[196] It is suggested here that this task is not something each juror should do arbitrarily, but that they would require expert opinion to assist them. If the direction in *Elliott* can be construed as inviting the jury to make the adjustment without technical expert evidence, then this is quite inappropriate.

Hunt J's decision was to admit the evidence as to the testing and matching of the samples, but he held the assessment of the odds to be inadmissible. His reason was that the odds were only stated within a certain "confidence level", the range of odds being 176 to 156 with a confidence level of 70%. As was learned in the *Andrews* case, separating the statistics from the evidence as to testing and matching DNA is not a proper approach. With respect, His Honour's judgment displays a lack of appreciation of the statistical component involved in analysing DNA results.

In terms of the Bayesian likelihood ratio, the population data caused the Court great confusion in formulating an alternative hypothesis. The fact that the crime stain was found on the suspect, not at the crime scene, is all-important. The denominator of the likelihood ratio that should have been considered is the *probability that Elliott would have "this" blood stain (E) on his clothing if he did not stab the victim (C)*.[197] This question requires a study of the suspect's lifestyle and movements, which will determine the type of population to survey for band sharing data. Is Elliott a member of a group that is likely to have someone else's blood on his or her clothing, such as an ambulance driver, sportsperson, parent or violent gang member? If not,[198]

> [t]aking this to its final conclusion, the finding of non-self blood on an office worker would result in a larger likelihood ratio than the same finding on a gang member.

Where the body sample transfer is from the scene to the suspect, then details about the suspect are irrelevant. Obviously the court

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196 Above n 194, 25

197 See B Robertson and A Vignaux, above n 74, and J S Buckleton, I W Evett and K A J Walsh, above n 78.

198 J S Buckleton, I W Evett and K A J Walsh, above n 78, 8

required further information about why the accused might have blood on his clothing. This possibility was not even mentioned in the judgment. Nor was there reference to the number of bloodstains found on Elliott's clothing, or to whether a sample of Elliott's own blood was analysed.[199] The laboratory's practice of declaring matches and non-matches at a particular cut-off point might also be criticised on the basis discussed in this paper, although this point was not raised at the hearing.

8.2 *R v Tran*[200]

A question about the admissibility of DNA evidence arose part way through the rape and murder trial of Van Hung Tran. For the Crown, Cellmark Diagnostics had performed DNA tests on vaginal swabs and a bloodstain from the deceased, and samples from the deceased's parents. A combination of different probes were used, but a result from only one single locus probe was relied on. The analyst's conclusion was that the chance of an unrelated individual matching the bands from the stains was one in 152. The other main piece of evidence against Tran was an eyewitness identification by the victim's boyfriend, on the basis of his Vietnamese appearance.

The defence called five expert witnesses, who testified about two main problems with the evidence. Firstly, there was considerable dispute about whether two faint bands from the crime sample were sufficiently clear to "match" with those in the accused's profile. The experts gave detailed evidence about the reading of bands, and the process of matching and measuring them. Incidentally, Cellmark's set criteria (standard deviation) for determining matches and non-matches was not challenged.

The second major difficulty was with the population database. The accused was Vietnamese, whereas the database used by Cellmark had no relationship to this ethnic group. It was composed of Caucasian, Afro-Caribbeans and Asians. The most conservative band sharing ratio out

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199 As was pointed out by B Robertson and A Vignaux, above n 74.

200 (1990) 50 ACrimR 233 (Sup Ct NSW), McInerney J

of these three groups (Afro-Caribbean) had simply been adopted as the basis of the Crown witnesses' mathematical calculation.[201] The result was a likelihood ratio which was, at best, an approximation.

In recognising the need for data relevant to the suspect's ethnic group, the Court had implicitly formulated the correct alternative hypothesis to be compared. Where the body sample transfer is from the offender to the scene, band sharing amongst all *possible* offenders needs to be surveyed, and information about the suspect's lifestyle becomes irrelevant.[202] The population surveyed in *Tran* had to be modified because of the extra background information from the eyewitness identification that the offender was Vietnamese. Although it is not made clear in the judgment, without the eyewitness connection the best that could have been done is to model bandsharing in the general population, despite the fact that the suspect himself was Vietnamese.

The Judge decided not to admit the DNA evidence, concluding that it:[203]

> would have a tendency to produce a misleading and confusing impression for the jury... I am of the opinion that the jury would not be in a position ... to determine the issues ... I believe they would be speculating ... [T]he state of the evidence is unsatisfactory because of the fact that there is no database for Vietnamese.

As an alternative ground, McInerney J would have exercised his discretion to exclude the evidence on the basis that its weight was outweighed by its prejudicial influence on the minds of the jury.

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201 The different band sharing ratios from these groups gave odds ratios of 1 in 152 (Afro-Caribbean), 1 in 200 (Caucasians), and 1 in 243 (Asians): ibid, 235

202 See J S Buckleton, I W Evett and K A J Walsh, above n 78, 4

203 Above n 200, 242

V. CONCLUSION

DNA profiling is a dramatic step forward in the field of forensic science. This new technology has the potential to provide a form of evidence to judges and juries upon whose accuracy and reliability they can rely with confidence. DNA testing is no doubt about to take New Zealand's criminal justice system "by storm", and in the paternity context, it is envisaged by many that DNA profiling will eventually render conventional blood tests redundant.

In order to preserve the potential of this scientific procedure, still in its infancy, calls for scrutiny and caution in assessing the value of DNA evidence are made within both the scientific and legal communities. The first wave of challenge to this technology being presented as evidence in court, questioned the accuracy and reliability of DNA testing. Numerous authors have advocated that laboratories need to be regulated by uniform standards and protocols for quality control. In the writer's opinion, however, this aspect of DNA profiling will always be heavily reliant on the individual skill and integrity of scientists.

More recently the focus of challenges to the reliability of DNA evidence has begun to shift to how the DNA results are interpreted. Courts are now grappling with even more difficult questions about population genetics and statistical methods. It is because of this further aspect of the evidence that:[204]

> counsel need more than an understanding of the technique of DNA profiling *per se*. A knowledge of the science of analysis generally would [be of great benefit].

There are inherent problems in calling on lawyers, judges and jurors, none of them trained in science or statistics, to conduct a critical evaluation of DNA evidence. Many of the difficulties are encountered in all forensic scientific evidence, and in expert testimony generally. But there are ways of minimising the

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204 S J Young, above n 17, 267

technicality, confusion and overbearing influence of scientific evidence, and greater advantage needs to be taken of these. One way is pre-trial consultation between the experts and lawyers about the contentious aspects of the evidence. Another is presenting DNA evidence as a "likelihood ratio of two relevant, positive and specific hypotheses"[205], which, it has been suggested, is the most simple, least confusing way of conveying DNA results.

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205 B Robertson and A Vignaux, above n 74

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Appendix A

PATERNITY ANALYSIS

1. INTRODUCTION

DNA Diagnostics has performed fingerprinting analysis on the samples below. The analysis uses the fact that the bands that are scored in these tests are inherited. Half of an individual's bands should be inherited from their mother, and half from their father. There should be very few (if any) bands in a child that are not present in either the mother or father.

2. SAMPLES ANALYSED

Blood donor	Bands scored	Probes & enzymes used
Mother: X	N_m =	
Child: Y	N_c =	
Father: Z	N_f =	

3. ANALYSIS OF CHILD'S BANDS

Number of bands in common with mother, M =
Number of bands in common with father, P =
Number of bands in common with both, B =
Number of bands in common with neither, U =

4. PROBABILITIES

The probabilities of obtaining the results above have been calculated (as explained in the accompanying sheets), on the basis of two hypotheses:

Hypothesis 1. Z is the biological father of Y.

Calculated probability =
Therefore reject/fail to reject hypothesis 1

Hypothesis 2. Z is not the biological father of Y

Calculated probability =
Therefore reject/fail to reject hypothesis 2

The following results are unusual or atypical in this case:

5. CONCLUSION

It is the conclusion of DNA Diagnostics that: Z is the biological father of Y
Z is not the biological father of Y

Appendix B

...paternity report ref:91/43
Analysis of results:

The following statistical calculations and conclusions have been produced from examination of the test results in this case:

1. It is not possible to exclude [redacted] from being the mother of [redacted] and it is not possible to exclude [redacted] from being the father of [redacted]

2(a) The percentage of random males excluded from paternity of the child [redacted] born to [redacted] is 99.8%.

(b) The chance for a random male to father a child with the same test results as [redacted] with this mother, is 1 in 71,429.

3. The odds ratio for [redacted] being the father of the child is 322:1. The odds ratio is the number of times that [redacted] is more likely to be the father of the child than is a random male.

In conclusion:

[redacted] has a high probability for paternity of the child [redacted].

Statistical evaluation of this case shows that a very high proportion of random males can be excluded from paternity. The set of tests will therefore exclude with virtual certainty a male who is wrongly alleged to be the father.

Yours faithfully,

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