Impact of DNA Typing on Standards and Practice in the Forensic Community

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• This article reviews the history of DNA-based human identification from its inception in 1985. Since the development of the technology, experts called for setting of standards and use of proficiency tests for quality assurance measures. The response of the National Institute of Standards and Technology to DNA forensic standards needs was catalyzed by the Technical Working Group on DNA Analysis Methods, sponsored by the Federal Bureau of Investigation with funding provided by the National Institute of Justice. Standard reference materials were developed for the original technologies used in DNA identification and for the newer polymerase chain reaction–based technologies. Adoption of recommended standards developed through the Federal Bureau of Investigation–commissioned DNA Advisory Board show the acceptance of National Institute of Standards and Technology standards for calibration of laboratory protocols. New technologies will require a process of validation and continued testing through the use of proficiency tests, such as those provided through the College of American Pathologists. Robotics and parallel processing of samples will lead to increased efficiency in DNA testing. The use of DNA data banks of convicted felons will increase dramatically with the the Federal Bureau of Investigation's national implementation of a computerized identification system known as the Combined DNA Index System. This system that will make major use of short, tandem, repeat genetic systems and will be the major driver of technology for the next 5 to 10 years. Finally, sample collection and training are of major concern for those who look at the long-term impact of DNA testing in forensic laboratories.

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HUMAN IDENTIFICATION BY DNA TYPING: THE DIFFERENCES BETWEEN DNA FINGERPRINTING AND DNA PROFILING

DNA analysis has its scientific roots in classical genetics, biochemistry, and molecular biology. The rapid adaptation of DNA analysis in the clinical arena suggests that the College of American Pathologists will soon have a large number of DNA diagnostic tests to assess by way of new surveys. In the field of forensics, DNA typing began in the United Kingdom when a molecular biologist, Alec Jeffreys,[1] used microsatellite analysis in a case of disputed parentage in an immigration case.

In the United States, adoption of some of Jeffreys' techniques led to forensic use of DNA testing on a limited basis. The first US criminal conviction of a DNA case was that of *Florida v Andrews*[2] in 1986. A decade later, Dr Jeffreys, who by then had earned the distinguished title of Sir Alec Jeffreys, had an interview that was published in the Institute for Scientific Information newsletter *Science Watch*.[3] In the interview, Dr Jeffreys stated, ''Unfortunately—and particularly in the United States—the term 'DNA fingerprinting,' which we specifically apply to the original multi-locus system in which we look at scores of markers, has been corrupted to be used in almost any DNA typing system [and] that has created a problem in court, because DNA profiling does not produce DNA fingerprints . . . So this is a semantic problem . . . Now, if we get rid of that semantic part, we can ask how valid is the huge amount of debate that's gone on about the reliability of DNA profiling? In the early days, in particular, there was real cause for concern. Some of the laboratories doing this work were carrying out real forensic analysis with technology that had been very poorly validated and hadn't been standardized.'' Dr Jeffreys concluded, ''I think that this issue has been largely addressed now, through quality controls, the adoption of standard operating conditions, blind proficiency trials, and so on.'' Dr Jeffreys rightly identified some of the issues regarding quality assurance of DNA typing. However, he did not address the need for the development of reference materials traceable to a national or international authority.

CALLS FOR STANDARDS

In the early 1990s, as DNA typing began to take more of a role in human identification, criticisms began to emerge. Some important scientists, among them Eric S. Lander, a Harvard University research professor, publicly questioned the soundness of the DNA typing procedures used by some commercial companies. ''The general quality of DNA fingerprinting evidence currently being introduced into U.S. courts appears to be quite mixed,'' Lander told a House subcommittee in March 1992, ''largely due to an absence of rigorous accepted standards.''

Lander also stated in another interview in 1993, ''I think DNA will play a major role in shifting the way that courts

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proceed. It will really leave a presumption of guilt if the DNA does match . . . and that changes the way the courts work. In a way I worry about that. I don't worry about it when it is done right. When it is done right I'm very much in favor of seeing guilty people convicted and innocent people let go.'' Lander then stated, ''I'm not worried about the use of DNA in the courts. But it requires constant vigilance, and I think that's something we will have to work very hard to make sure continues.'' In answer to questions regarding ensuring vigilance, Dr Lander stated, ''I think it is crucial to have mandatory proficiency testing and regulation of laboratories. This is not a situation where the free market is going to take care of it. We really need the government, in the form of the federal government, to step in and set standards for proficiency testing, so that every examiner who does DNA testing who is going to court is tested on a regular basis, perhaps an annual basis, to be sure that they can do this carefully, that they don't mislabel samples. You need to have blind testing. This is done in all sorts of medical specialties. It is taken as routine that people have to continue to demonstrate their proficiency at an activity. It seems to me crazy that higher standards of proficiency should be demanded for those who test for Strep throat than, say, forensic examiners who test DNA that might lead someone to go to Death Row.''

Likewise, in its 1996 DNA report, *The Evaluation of Forensic DNA Technology* (National Academy Press, Washington, DC), the National Research Council reaffirmed that there be some degree of standardization to ensure quality and reliability. The report recommends that ''each forensic laboratory engaged in DNA testing must have a formal, detailed program of quality assurance and quality control.'' The report also states that ''quality-assurance programs in individual laboratories alone are insufficient to ensure high standards. External mechanisms are needed to ensure adherence to the practices of quality assurance. Potential mechanisms include individual certification, laboratory accreditation, and state or federal regulation.'' The DNA Identification Act of 1994 (Pub L No. 103-322) also provided for a DNA advisory board to set standards for DNA testing.

INTRODUCTION OF DNA STANDARDS BY NIST

The National Institute of Standards and Technology (NIST) began working with the Federal Bureau of Investigation (FBI)–sponsored Technical Working Group on DNA Analysis Methods in the late 1980s. From that interaction, a series of reference materials were prepared. The analytical community recognized these materials as important components of a quality assurance program. For example, in Deborah Noble's article[4] written in 1995, she described how ''the National Institute of Justice recently commissioned the National Institute of Standards and Technology (NIST) to develop a standard reference material (SRM) for forensic polymerase chain reaction (PCR) proficiency testing. As new PCR techniques come into play, the 20-component SRM kit should be useful for validating them and determining whether they can be used for forensic work.'' Since that time, SRM 2391 for PCR-based technologies has been used by a large number of forensic laboratories for calibration and standardization. Sales of the SRM have exceeded projections every year. Because of the sales depletion of the first set of SRM 2391, a replacement SRM 2391a will soon be available.

DEVELOPING THE STANDARDS

Before the introduction of a standard for PCR-based testing, NIST had produced a set of materials (SRM 2390) for DNA tests based on restriction fragment length polymorphism (RFLP) technology. The NIST SRM sets for forensic use and paternity testing are generally used to validate a laboratory's measurement capability, calibrate instrumentation, and troubleshoot protocols. The October 1998 DNA Advisory Board Quality Assurance Standards for Forensic DNA Testing Laboratories, promulgated by the FBI, state (section 9.5), ''The laboratory shall check its DNA procedures annually or whenever substantial changes are made to the protocol(s) against an appropriate and available NIST standard reference material or standard traceable to a NIST standard.'' Proper training and use of traceability standards will be a challenge to many forensic laboratories that have not previously had that element of quality assurance as part of their normal operating procedures. However, clinical laboratories are quite familiar with the process and have used the traceability process for many years.

IMPACT OF NEW TECHNOLOGIES ON FORENSIC LABORATORIES

After a decade of debate, much of the novelty of DNA testing has diminished, but the capability and extent of forensic DNA typing continue to develop. Discussions are continuing on the necessity and mechanism of blind proficiency testing and oversight of forensic laboratories. As new methods of DNA analysis come into use, as new loci within the human genome become identified as useful forensic markers, and as DNA samples from other organisms are tested, new evidentiary issues will arise. This rapid influx of technologies has affected crime laboratories and underscores the necessity of good validation studies and quality assurance procedures for acceptance of relevant data in the courts.

Understanding the variables inherent in a measurement system that deals with human identification is fundamental to a good quality assurance program. As an ongoing project, NIST has also published a series of articles dealing with various aspects of interlaboratory comparisons of the RFLP process.[5–9] This series deals with identifying and quantifying sources of variation in RFLP testing. Other relevant NIST research has focused on various factors associated with interlaboratory testing of forensic methods.[10,11]

Another laboratory technology that is gaining more usefulness in the forensic laboratory is the identification of human remains through PCR amplification and DNA sequencing of mitochondrial DNA, which is inherited only through an individual's maternal line. In casualties where the remains aren't easily identifiable, the identity of a victim can be verified by comparing mitochondrial DNA sequences with those of siblings or maternal relatives of the deceased. Production of a NIST SRM for mitochondrial DNA sequencing is in its final stages, with release of the material slated for the third quarter of 1999.

Other technological developments that will possibly affect the forensic community are being introduced at a rapid rate. One of the more practical developments is the ability to preserve DNA samples on treated filter paper to eliminate bloodborne pathogens and to stabilize DNA for long-term storage at ambient temperatures. Rapid developments in robotics are leading to the automation of sam-

ple extraction. A huge leap in analysis capacity in large laboratories is made possible by the rather expensive parallel capillary array instrument just released by Perkin-Elmer/Applied Biosystems. Additionally, large throughput of samples might be possible through the use of MALDI-TOF mass spectrometry. Finally, the introduction of DNA chip technologies or ''Lab on a Chip'' technologies may be forthcoming in the next few years.

CODIS AND SAMPLE COLLECTION

The DNA Identification Act of 1994 was designed to improve the capability and quality control in state and local crime laboratories. This legislation also authorized the FBI director to establish a national DNA identification index and provides penalties for the disclosure of DNA data held by data banks that participate in the Combined DNA Index System (CODIS). CODIS facilitates the exchange of information in DNA data banks in different states. CODIS coordinates a data bank that will store digital information from DNA samples from thousands of convicted criminals across the country.

A DNA data bank was first used in 1991 to identify a criminal suspect accused of the rape and murder of a 23-year-old Minneapolis woman. A sperm sample was the only clue police had to go on. However, a search of Minnesota's data files of DNA RFLP profiles from convicted offenders revealed the link that detectives needed. The DNA profile from the sperm sample matched the DNA profile obtained from a formerly convicted sexual offender, Martin Perez. Perez was swiftly tried and convicted.

The FBI initiated a pilot program for CODIS in 1990 involving 10 laboratories. A survey conducted in October 1993 showed that crime laboratories already had collected about 142 000 samples from convicted offenders and analyzed more than 17 000 samples. Linkage of data banks from Illinois, Minnesota, and Virginia was sufficient to successfully locate several suspects and find associations among unresolved cases. Now, about half of the states either have or will soon have input into the national CODIS system. By late 1997, CODIS database submissions increased to more than 85 000 samples, all RFLP based. With STRs becoming the new paradigm, many previously entered RFLP profiles will need to have new blood samples from the donors for STR profiles to be entered into the CODIS database.

It is likely that CODIS will be the major driver for implementation of an STR-based standardized set of DNA profiles. It is expected that many of the older technologies will become less popular as STRs become the de facto standard. The level of expertise of the forensic analyst will have to increase so that they can correctly interpret complex patterns from capillary electrophoretic printouts. This expertise will be of particular importance when mixed stains are encountered.

Finally, when samples come from crime scenes, the expertise and experience of forensic scientists cannot be overestimated. Just as highly focused specialists in one field may be unaware of specific applications outside their field, so also may scientists who previously have not dealt with forensic samples be unaware of factors that are case specific and other issues that can confound the interpretation of test results. The need for training in crime scene detection and sample collection is still of major concern for those who look at the long-term impact of DNA testing on forensic laboratories.

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