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Technology Assessment

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DNA Profiling: For Positive Identification

Introduction

Taking fingerprints at the scene of a crime is standard practice. Now, the technology of DNA profiling (or DNA fingerprinting) is fast becoming a scientifically and legally accepted means of making positive identification from body fluids and hair left at the crime scene.

Superior to traditional methods of identifying persons, this technology uses sophisticated laboratory techniques (electrophoretic testing of genetic marker evidence) deemed to be extremely accurate when run by a qualified laboratory.

In a keynote address before the 41st Annual Meeting of the American Academy of Forensic Sciences, FBI Director, William S. Sessions, said, "DNA profiling has now become a formidable weapon in our arsenal against violent crime. In the near future, crime laboratories across America should be able to analyze hair, blood, or other body fluids left at the scene of a crime and make an identification."¹

History/Background

DNA profiling was first used in genetic research and then for determining

¹ From Director William S. Sessions' keynote address at the 41st Annual Meeting of the American Academy of Forensic Sciences, Las Vegas, Nevada, February 20, 1989.

paternity cases in the 1970's. As technology developed, DNA testing methods have become highly advanced using electrophoresis and radioactive isotopes. In 1985, a British geneticist, Dr. Alec Jeffreys of the University of Leicester, wrote about the DNA probe showing how individuals could be identified on the basis of their DNA. Since then, with legal acceptance, DNA profiling technology has grown rapidly.

No State courts have denied DNA profiling as evidence. DNA fingerprinting has also passed the so called "acid test" of a ruling in an appellate court. (See "DNA—The New Fingerprints," May 1, 1988, *ABA Journal*, p. 66.) Florida's 5th District Court of Appeals upheld the admissibility of DNA fingerprinting in the first appellate decision concerning such evidence in a criminal case. Tommie Lee Andrews was convicted, in November 1987, of aggravated battery, sexual battery and armed burglary of an Orlando woman. DNA tests compared Andrews' blood with semen found in the victim. The Florida appeals court upheld the admission of the evidence against Andrews, saying "evidence derived from DNA print identification appears based on proven scientific principles." (*Andrews v. State of Florida*, No. 87-2166, October 20, 1988.)

What is DNA?

DNA (or deoxyribonucleic acid) is the material found in the nucleus of human cells that contain our chromosomes. It

provides the genetic code that determines the finite building blocks that make up our individual characteristics. In the entire human genetic code there are about 3 billion building blocks which are called nucleotides. These nucleotides are arranged in a specific sequence similar to the supermarket bar codes that distinguish one product from another. From a DNA sample of human body fluids or tissue specimens identification can be probed.

By probing a DNA sample with these various specific DNA building blocks, scientists can narrow down and identify distinguishing traits such as those found only in members of the same family. For example, DNA profiling of a mother and son will demonstrate a high number of shared bands or building blocks, since half of the individuals' DNA genetic codes came from the mother and half from the father.

A DNA probe is done by separating the DNA fragments. Many will contain repeated sequences that occur throughout the chromosome. It is possible to purify these repeated sequences, and then label them with radioactivity to enable detection. These radioactive sequences are known as "probes." Thus, the more DNA fragments that are identified by probing, the more exact is a person's DNA profile.

Each probe binds to a different area of a person's chromosomal DNA. Most labs try to get results from a minimum of four

probes. Using fewer than four probes may not reveal enough individual characteristics. After using four or five unique probes of a DNA sample an almost infinite arrangement of band patterns are revealed to identify or "fingerprint" a person's uniqueness. Identical twins will have an identical DNA profile, but all other individual's total chromosome set remains unique.

With the use of multiple probes, one can identify an individual to a certainty of one in a million. DNA can be determined through the use of dried body fluids, stains, semen, saliva, and even follicular cells of one strand of hair if newer amplification techniques are used. The most commonly tested biological samples are blood and semen. Under ideal conditions, a freshly dried human biological specimen will provide the most easily tested information. But scientists have been successful in obtaining a DNA profile from forensic samples that are over 8 years old and DNA testing has even been successfully completed on a 2,400-year-old Egyptian mummy.

Who is testing today

Some of the leading test facilities today are found both in Government and in the commercial marketplace. The Federal Government's involvement includes testing, evaluating standards, quality assurance, and quality control. Some concerns have been expressed over the admissibility of evidence supplied by commercial laboratories, because of a few court cases that revealed one laboratory's shift in strict adherence to matching rules. However, the work of commercial laboratories both in the United States and elsewhere have established DNA profiling as admissible evidence in the courts. The following labs participated in groundbreaking work in the field of DNA testing:

- FBI Laboratories (in Quantico, Virginia, and in Washington, D.C.).
- Cellmark Diagnostics, Germantown, Maryland.
- Lifecodes Corporation, Valhalla, New York.
- Cetus Corporation, Emeryville, California.

- National Institute of Standards and Technology, Gaithersburg, Maryland.

Acceptance in court

In the 1923 precedent-setting case of *Frye v. United States*, the U.S. Court of Appeals for the District of Columbia Circuit Court reviewed the admissibility of evidence based upon a relatively primitive polygraph technique and ruled as follows: "Just when a scientific principle or discovery crosses the line between experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while the court will go a long way in admitting expert testimony deduced from a well recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs."² Thus, the "Frye standard" was established for the introduction of new technologies into a court case.

More recently, in an article titled, "DNA Testing and the Frye Standard,"³ the author Robert A. Fiatal, a legal instructor at the FBI Academy, says, "Numerous courts, to include several at the appellate level, have assessed the admissibility of expert conclusions based upon the DNA identification process. Courts to date have carefully considered the expert testimony of scientists from the fields of molecular biology and genetics and consistently agreed that the principles underlying the DNA technique are universally accepted." Fiatal adds, "Based on such expert testimony, these courts have also, without exception, recognized that certain DNA testing protocols are generally accepted as producing reliable and accurate results that satisfy both the Frye and relevancy standards of admissibility. Moreover, the overwhelming majority of these courts have determined that these procedures were properly employed by the testing laboratory." Fiatal also suggests that

² "DNA Testing and the Frye Standard," Robert A. Fiatal, *FBI Law Enforcement Bulletin*, June 1990, Vol. 59, No. 6: 26-31.

³ *Ibid.*

success in the courts ultimately depends on the ability of the expert witnesses to explain to the court the scientific validity of the DNA process used and the particular conclusion or identification made.

The first test case

DNA testing was first used as admissible evidence in a test case in Great Britain. In the early 1980's, Alec Jeffreys, then a graduate fellow at Leicester University, discovered a class of complex DNA probes that are called multi-locus probes, differing from the conventional single-locus probes that provide a greater probability of genetic matching.⁴ Upon publishing his work he was then asked to conduct the new DNA test on a human biological sample taken from a boy who was denied entry into the United Kingdom because immigration officers doubted his identity as the son of a Ghanaian woman who was entitled to live in Great Britain. The test concluded that the boy was indeed the woman's son. The DNA profile showed a high number of shared DNA bands between mother and son. The chance of such a match occurring at random is about 30 million to 1. Following that case, DNA testing was conducted on about 40 immigrants where a parent-child relationship is fundamental to the claimant being able to enter or remain in the United Kingdom. At the same time, DNA tests were also being conducted on a youth held in a British prison for 3 months on a charge of murder. The DNA tests on his blood and saliva samples showed that the accused young man was not the murderer.

Other cases of interest

Another DNA case was described in *Law Enforcement Technology*, November/December 1988: "In late October 1988, New York State convicted its first offender with this [DNA] methodology. Jurors, who were briefed on DNA by an expert witness from a commercial lab, Lifecodes, in Valhalla, New York, stated that the genetic analysis played a large part in finding the defendant guilty. In

⁴ "Positive Identification of an Immigration Test Case Using Human DNA Fingerprints," Jeffreys, Brookfield and Semenoff, 217 *Nature* 318, 1985.

this case accused sexual abuser Victor Lopez was linked through the DNA in his blood to DNA found in the nuclei of the sperm cells taken from one of the three rape victims. The DNA played such a major role because there had been discrepancies in the suspect's description."⁵

In *Cobey v. State*, a Maryland Court of Appeals upheld the admission of identification testimony based upon the DNA analysis performed by Cellmark Diagnostics, a private testing laboratory founded by Dr. Alec Jeffreys, in Germantown, Maryland. The laboratory established a match between the defendant's blood and semen stains found on the undergarments of the victim of a sexual assault. Along with the laboratory report, the court relying upon the testimony of the government's five expert witnesses, concluded that the procedures were generally accepted, satisfied the Frye standard, and were reliably administered. The court further found that the laboratory used acceptable criteria for formulating the minuscule chances of the match occurring randomly.

Through various test cases in the courts, DNA profiling has proven to be a viable investigative procedure for law enforcement and prosecution. It can be used to identify the perpetrator of a crime and exonerate the innocent. Court acceptance of DNA profiling has been established by using the Frye standard; and by obtaining the traditional evidentiary test of relevance, where scientific evidence is deemed admissible if the testifying expert is duly qualified.

The Supreme Court of Oregon recommends covering the following points when assessing the relevancy of evidence that is based upon a new scientific approach:

- 1) The testifying expert's qualifications.
- 2) The existence of specialized literature about the procedure.
- 3) The use of the procedure.
- 4) Its potential for error.

⁵ "DNA Breakthrough Has No Match," Donna Rogers, *Law Enforcement Technology*, November/December 1988, pp. 16-18.

5) Its general acceptance in the relevant scientific community.⁶

Standards and quality assurance

Dr. Dennis Reeder, Group Leader of Bioanalytical Techniques at the National Institute of Standards and Technology (NIST), is conducting studies that evaluate DNA standards. NIST is examining experimental protocols, and is assessing the suitability of a variety of size markers and cellular DNA controls for use as standards for quality assurance.

Also under standards consideration is the feasibility of a DNA retrieval or indexing system to quickly identify individuals whose DNA is on file. One of the first steps needed is to establish a data base of sex offenders. Another concept is to establish a data base of the DNA profiles of all children; a blood sample would be taken at birth and the DNA profile entered into the system.

It is anticipated that there will be a movement away from eyewitness testimony to forensic testimony that will, in turn, affect policing and research methods.

To further establish standard procedures in DNA profiling, the Forensic Science Research and Training Center (FSRTC) of the FBI Laboratory in Quantico, Virginia, has made a major effort in developing methodology and validating the application of DNA analysis to forensic biological specimens. The restriction fragment length polymorphism (RFLP) analysis is a favored DNA profiling method used by the FBI and nearly every other laboratory reporting DNA results. The RFLP method is reported by Bruce Budowle of the FBI lab to be "extremely sensitive, reproducible, reliable, simple, and relatively inexpensive."⁷

James L. Mudd of the FBI Laboratory in Quantico has stated: "It is essential that the quality of the analytical data be monitored to ensure that the accuracy and

⁶ June 1990 issue of *FBI Law Enforcement Bulletin*, p. 27.

⁷ "The RFLP Technique," Bruce Budowle, *Crime Laboratory Digest*, Vol. 15, No. 4, October 1988, pp. 97-98.

related performance characteristics of the procedure are maintained. Further, the nature, quantity, and condition of forensic samples require appropriate standards and controls to ensure reliable and reproducible interpretation. One way to provide reliable evidence that the data generated by an analytical procedure is scientifically sound is through the implementation of detailed, but flexible, quality assurance [QA] and quality control [QC] programs."

Testing will produce either a viable DNA profile or no reading at all. Further, there are no false positive readings. Results of a DNA profile test are either positive or inconclusive.

How DNA testing can help your department

What does DNA profiling mean for the law enforcement professional in the field? Forensic experts say the accuracy allows investigators to settle violent crime and sexual abuse cases that might have gone unsolved because of insufficient evidence.

Since the DNA genetic code is identical in all body cells, almost any biological material can be submitted for DNA typing. Profiling depends on isolation and characterization of the DNA components of nucleated cells, such as those found in seminal fluid, white blood cells, hair follicles, skin, or muscle tissue. The accuracy of DNA profiling opens the doors for improved investigations and conclusive evidence.

You do not have to be part of a large metropolitan unit to take advantage of DNA testing. Small departments without a DNA testing lab have access to this new technology through the FBI Laboratory and several private commercial laboratories that can provide genetic evaluations.

How to collect and preserve DNA samples

In light of the revolutionary benefits of DNA typing, evidence-gathering techniques might be worth reviewing. Basically, investigators should follow the same precautions they use in collecting and preserving other biological evidence.

Prior to collecting a sample, leave the evidence where it is and photograph it with a scale or measuring device to give the forensics laboratory personnel an idea of the size. Then collect the evidence using the same care you have always followed in other investigations. You can collect any biological material, but need to be especially careful about storage, since bacteria and storage in moist conditions can degrade DNA. To avoid deterioration, never put the sample in an airtight plastic or glass container because they tend to keep the samples moist. Instead, allow the sample to air dry, seal it in a paper envelope, and freeze it.

Collect as large a sample as possible. One drawback of DNA typing is that the test is impossible if the sample is too small. Generally, blood stains should be at least 0.25 of an inch in diameter, though they can occasionally be smaller if the stain is in excellent condition. If the stain is on blue jeans, an even larger sample is needed because of difficulties in extracting DNA from that fabric. For semen samples, a minimum of one swab is required, and samples can be obtained using a traditional rape kit. As little as one hair follicle can yield sufficient DNA, but those DNA procedures are still in the experimental stage. Laboratories prefer working with more evidence if it is available. Your forensics department or private testing laboratory can provide more detailed guidelines.

Most labs prefer to see the sample on the original piece of material, but that is not always possible. Of course, you are not going to be able to bring in the section of a wall that was splattered with blood. In that case, you should transfer the evidence to a cotton swab moistened with distilled water, using as little liquid and collecting as much stain as possible. Then treat it as you would other samples.

Inquiries regarding the submission of evidence to the FBI Laboratory for DNA analysis or the case acceptance policy should be directed to the FBI Laboratory's DNA Analysis Unit, FBI Laboratory, Washington, D.C. 20535. Telephone: 202-324-5436. (If sending evidence, send to the address above and indicate to Attention, Evidence Control Center.)

Training

In January 1989, the FBI Laboratory's FSRTC, in Quantico, Virginia, began offering classes to State and local crime laboratories on DNA analysis. Each 4-week class is a combination lecture/laboratory course accredited through the University of Virginia.⁸

Recently, the Office of Technological Assessment (OTA) of the U.S. Congress held hearings on DNA typing and forensic applications at which it was decided that reliable standards, data bases, and a quality assurance program are needed. The OTA report will be published in 1990.

Obstacles to accepting DNA technology

The fourth amendment to the U.S. Constitution might very well become an obstacle to this developing technology. This amendment covers Americans' right to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures. FBI Director Sessions warns, "We must proceed with care in this area, regardless of whether the Federal Government builds its own data base or leaves that to the States. The drawing of blood for a DNA profile may be seen as far more intrusive than the rolling of fingerprints. The right of society to be free from the fear of crime must be balanced by the constitutional rights of the individual—even if that individual is an accused criminal."⁹

Dr. Dennis Reeder of the National Institute of Standards and Technology also says this technological breakthrough has raised a number of legal questions, particularly concerning civil rights that must be addressed by the legal community.

⁸ Information about DNA training can be obtained by contacting Steven Allen at the Forensic Science Research and Training Center (FSRTC), FBI Laboratory, Quantico, Virginia 22135. Telephone: 703-640-1113.

⁹ Guest Editorial, William S. Sessions, reprint from *Journal of Forensic Sciences*, September 1989.

The variety of DNA testing methods creates further obstacles. To characterize DNA, there are several methods used by different labs, and each results in a different banding pattern. However, test results *can* be compared.

The future of DNA profiling

Today, DNA profiling methods have proven that almost any dried human biological material can be put through the DNA fingerprinting process and establish positive human identification beyond all reasonable doubt. The ability to classify such information, catalog it, and later run it through a search and compare it with other test results is critical for law enforcement. This will change the forensic investigative process and the legal process for positive identification in cases that relate to rape, incest, murder, kidnapping, unidentified and missing persons, paternity, maternity, and many more applications to come.

Data base building

The FBI presently maintains a file of over 100 million sets of fingerprints. Over the years this file has more than proven its worth in criminal investigation and identification. In time, a comparable DNA file could provide even more detailed data.

Edward Imwinkelried, a professor of evidence at the University of California at Davis Law School, strongly advocates building such a file, "Until a national data base is established, DNA typing's value as an investigative tool is minimal."¹⁰ Keith Monson of the FBI adds, "The necessity to rapidly and objectively analyze hundreds or thousands of forensic DNA autoradiograms requires that computer-assisted methods of analysis and data management be developed."¹¹

The FBI's FSRTC laboratory has produced a prototype DNA analysis system on a microcomputer and a general-purpose image processing system. After

¹⁰ "DNA—The New Fingerprints," Debra Cassens Moss, *ABA Journal*, May 1, 1988, p. 66-70.

¹¹ *Ibid.*

Appropriate testing of the system by selected laboratories, the software will be made available to all qualified scientists. In addition, commercial firms, such as BioImage of Ann Arbor, Michigan, have developed more sophisticated software and hardware based on minicomputers.

But much work remains. Larger population studies need to be done. Studies of the effects of various environmental conditions and hazards on amplification and typing of DNA are now being conducted. Amplifications of certain regions within genes will result in greater understanding of how to identify variables among individuals.

A better method of identification

Clearly, persons could be identified by searching through a large data base of DNA profiles. Information gathered for this data base could be developed in much the same method that is presently used to take a baby's footprints at birth. Fingerprints are now taken for the identification of large populations of people, including military personnel, all government employees, and persons arrested for suspicion of a crime.

Criminals might go to great means to disguise their true identity; although they might grow a beard, change hair color, or even have facial plastic surgery, the DNA test would clearly identify perpetrators if they had been previously tested and their DNA profile stored in a data base. Identification would be unquestionably accurate, as would be the identification of "unknowns." Unsolved violent crimes could be linked from DNA data gathered from captured violent criminals along with DNA profiles obtained from human biological samples taken at the scene of a crime. Genetic samples from the parents of missing youth could be matched with DNA samples made from street vagrants and unknowns to aid in locating lost youth.

Today labs can run various levels of DNA testing that will either rule out or establish the proof of either the victim's or the perpetrator's identity. Clearly, DNA testing is a viable and exciting tool for gathering criminal investigative material.

Finally, a note of caution from FBI Director Sessions, "I am excited about DNA's tremendous potential for law enforcement, and I know the forensic science community is also. But we need to proceed calmly, rationally, and judiciously."¹²

Selected reading

- "DNA Fingerprinting: Possibilities and Pitfalls of a New Technique," Dan L. Burk, *Jurimetrics Journal*, Summer 1988, Vol. 28, No. 4: 455-471.

- "Convicted by a Hair: DNA Testing," John A. Tarantino, *Criminal Justice*, Summer 1989, Vol. 4, No. 2: 4-7, and 41-43.

- "DNA Fingerprinting," Georgia Criminal Justice Coordinating Council, Criminal Justice Study Brief 3, Summer 1988, 5 p.

- "DNA Testing and the Frye Standard," Robert A. Fiatal, *FBI Law Enforcement Bulletin*, June 1990, Vol 59, No. 6: 26-31.

- "Guidelines for a Quality Assurance Program for DNA RFLP Analysis," James L. Mudd, *Crime Laboratory Digest*, April-July 1989, Vol. 16, No. 2: 40-59.

- "DNA—The New Fingerprints," Debra Cassens Moss, *ABA Journal*, May 1, 1988, pp. 66-70.

- "DNA Breakthrough Has No Match," Donna Rogers, *Law Enforcement Technology*, November/December 1988, pp. 16-18.

- "DNA Profiling: A Tool for Law Enforcement," John W. Hicks, *FBI Law Enforcement Bulletin*, August, 1988, reprint, 5 p.

- "Method and Applications of DNA Fingerprinting: A Guide for the Non-Scientist," R. F. Kelly, J. J. Rankin, and

¹² From Director William S. Sessions' keynote address at the 41st Annual Meeting of the American Academy of Forensic Sciences, Las Vegas, Nevada, February 20, 1989.

R. C. Wink, *The Times, The Criminal Law Review*, 1987, pp. 105-110.

- "DNA Typing: A Unique Weapon Against Crime," *The Scientist*, January 23, 1989, pp. 12-13.

- "DNA Analysis: Law Enforcement's Connection from Living Cell to Jail Cell," John W. Hicks, *The National Sheriff*, April-May 1989, pp. 34-35.

- "FBI Announces New DNA Policy," *Focus on Forensics*, March 1989, p. 23.

- Guest Editorial, William S. Sessions, reprint from *Journal of Forensic Sciences*, September 1989.

- "Methods of DNA Analysis Under Investigation in the FBI Laboratory," Bruce Budowle, Harold A. Deadman, Randall S. Murch, and F. Samuel Baechtel, *Crime Laboratory Digest*, January 1988, Vol. 15, No. 1: 8-21.

- (Entire issue) "DNA Implementation," *Crime Laboratory Digest*, Supplement No. 1, 1988, Vol. 15, 18 p.

- (Entire issue) "DNA: From Research to Casework," *Crime Laboratory Digest*, October 1988, Vol. 15, No. 4.

Milestones in DNA analysis implementation

1923—*Frye v. United States*, 293 F. 1013 (D.C. Cir. 1923). This case established standards for admission of evidence using a new technology.

1953—The double-helix structure of DNA was discovered by James Watson, an American scientist, and Francis Crick, a British scientist, at Cambridge University, England.

1970's—Paternity testing employing DNA analysis was used in legal actions.

1985—Advanced genetic testing methods were developed in England. (Jeffreys, Wilson, and Thein, "DNA Fingerprints and Segregation of Multiple Markers in Human Pedigrees,"

39 *American Journal Human Genetics* 11, 1986.)

1985—First successful test case in England. (See: Jeffreys, Brookfield and Semenoff, "Positive Identification of an Immigration Test Case Using Human DNA Fingerprints," 317 *Nature* 318, 1985.)

1986—FBI began research on DNA in Quantico, Virginia, at the Forensic Science Research and Training Center (FSRTC).

1987—DNA test first successfully used as evidence in the United States.

1988—First United States Appellate Court case to rule on admissibility of DNA identification tests. *Andrews v. State*, 533 So. 2nd 841 (Florida Appellate 5th District 1988).

1988—FBI open DNA labs in Quantico, Virginia, and in Washington, D.C.

1988—*People v. Wesley*. New York State Co. Ct. July 15, 1988. It was determined that the Lifecode print identification test met the Frye standard of admissibility (using DNA analysis).

1988—First appellate court ruling on the admissibility of DNA identification tests. In *Andrews v. State* (Florida Appellate 5th District 1988).

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