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DNA FINGERPRINTING

An Interactive Qualifying Project Report

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ABSTRACT

This report investigates the techniques used to obtain DNA fingerprints, their acceptance by both the scientific and law communities, and informs the public about the importance of DNA fingerprinting. The report first introduces the background information needed to understand what a DNA fingerprint is, then introduces both landmark and sensational court cases where DNA fingerprinting was used, and discusses the controversial topic of DNA databases. The report concludes with how DNA fingerprinting will impact society in the future.

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EXECUTIVE SUMMARY

DNA fingerprinting technology has revolutionized the way we think of the human genome and individuality. With scientific proof that the fingerprinting method can indeed identify each unique individual, the applications for the technology increase dramatically. Because the American justice system must investigate, solve and prosecute crimes, and must avoid convicting the innocent, the guilty must be identified beyond a reasonable doubt. This need has lead to better advances in the use of DNA fingerprinting technology, as well as the development of better methods of sample collection and statistical analysis of the results.

DNA, deoxyribonucleic acid, which is natural genetic material, determines the characteristics of all life forms. This chemical blueprint for humans contains the basic information of life and extraneous information. Because the required genetic information is mostly conserved (identical) from individual to individual, it is no use forensically. It is the extraneous information that we use in forensic detection. Each individual has a unique set of extraneous DNA – so unique that DNA samples can be linked back to their source through two DNA fingerprinting methods. RFLP and PCR DNA procedures make possible the detection of unique DNA base sequences from small pieces of evidence left at a crime scene.

The forensic applications of DNA fingerprinting are clear. DNA forensics begins at the scene of the crime, where both subtle and overt biological traces may be collected as evidence in a court of law. Because of highly published mistakes in evidence collection and contamination, crime scene collection techniques and lab processing procedures have recently emerged as extremely important facets of the detective work in

modern criminal cases. If properly collected, stored, and analyzed, these clues will yield their constituent DNA information, and hopefully establish a link between a crime and any involved individuals. Unique identification of a criminal should result in a conviction of the guilty, and acquittal of the innocent. As the frequency of use of DNA fingerprinting technology in the courtroom increases, so does the need to standardize and monitor the collection process. DNA profiling, especially PCR testing, is extremely sensitive to outside contamination, therefore it is essential that all evidence at a crime scene be collected quickly and stored properly.

In analyzing the impact of this technology on the criminal court system, in this IQP we examined the landmark court cases that have changed or made standard the DNA fingerprint technology. Landmark cases have proven that the technology can be valid for criminal investigations. Other court cases such as *People v Castro* have pointed to the need for standardized rules and procedures for DNA sample collection, analysis at the lab, and in the statistical methods used in calculating probabilities of matches. These cases have laid the foundation for our modern court system to handle DNA in an effective manner – supporting the prosecution's need to bring the guilty to trial, while protecting the defendant's right to examine and repute the evidence used against him. The new standardized scientific procedures guarantees both occur.

Next we analyzed sensational court cases, or those that have received media attention and were played out in the public forum. These cases have more influence on society and the public's perception of DNA fingerprinting than the landmark court decisions. The O.J. Simpson case was the first highly publicized case where DNA fingerprinting technology was put on trial and lost. Ongoing public DNA fingerprinting cases include the location of children through the Grandmothers of the Plaza of May

project, and identification of the victims of the World Trade Center Bombing. DNA fingerprinting has also been used to analyze the lives and deaths of historical figures such as Thomas Jefferson and Jesse James. Lastly, the technology is being used to reexamine issues surrounding infamous unsolved criminal cases such as the Boston Strangler.

In order to convict criminals, DNA fingerprinting experts need to have a strong grasp of the statistical chances of matching more than one person using any specific combination of DNA probes for the analysis. Ongoing biological research attempts to identify new rare segments of the human genome to use for forensic analysis. CODIS, a nationwide DNA database repository consists of two indices: an offender index and a forensic index. The offender index surveys unsolved crimes and attempts to match DNA fingerprints with past offenders. The forensic index samples the larger population from which the statistics regarding population genetics are derived. These statistics are what lend a given level of discrimination to a DNA profile. The American public has opposed any compulsory collection of DNA fingerprints from civilians fearing the private information could include medical predispositions and could become available to insurance agencies. The public fears that a misuse of this information could include denial of medical insurance or even job applications based upon future medical conditions. However, the public fails to realize that such genetic information is not present in the DNA database; it includes only the presence or absence of certain alleles not presently linked to any known disease. In the future, if a given allele is linked to a specific disease, then that allele information could be eliminated from the database. Also there is no information in the database linking any specific non-criminal individual to a given sequence. Population statistics also require racial based studies that raise questions on the ethics of studying racial boundaries.

Finally we conclude that DNA fingerprinting is an important technology for our criminal justice system, worthy of the claim of being the greatest forensic tool in the history of forensic science. We also conclude that firm planning and a commitment to privacy can avoid the negative aspects of the technology. Standardized collection of DNA and modernized lab procedures almost ensure that the technology will not be abused to convict innocent people. Database programs are valid as long as they are anonymous collections of data rather than samples tied to personal identification or medical records. DNA fingerprinting technology is too powerful a tool to suppress, and instead we need to create national guidelines for its use so that we may continue to reap the rewards of this important procedure.

PROJECT OBJECTIVE

This Interactive Qualifying Project (IQP) was aimed at investigating the impact of DNA fingerprinting technology on society. DNA fingerprinting, a relatively new technology, has revolutionized the way we investigate, solve and prosecute crimes. The social impact from the technology was analyzed in Chapters 3, 4 and 5 with respects to criminal and historical cases as well as current DNA database projects. As society increases its desire to punish the guilty, and free the innocent, we exchange our need for safety for our need for privacy. Our conclusion points to our agreement that the forensic power of DNA fingerprinting warrants its continued use, with proper attention paid to evidence collection, storage, and analysis.

CHAPTER ONE: BACKGROUND ON DNA FINGERPRINTING

What is DNA ?

DNA, deoxyribonucleic acid, which is a fundamental natural material, determines the genetic characteristics of all life forms. The human body contains approximately ten trillion cells. With the exception of red blood cells, each one of these cells has a nucleus, which contains DNA. While DNA is so small that can not be viewed under even the most powerful microscope, if stretched out it would measure six feet in length (Brinton and Liberman, 1994). A chromosome is a very tightly coiled strand of DNA that is found in the nucleus. Chromosomes are usually found in pairs. All humans have 23 chromosomes from each parent and therefore DNA is transferred from parents to their offspring (Berg and Singer, 1992). A gene is a specific section of a chromosome that is made of DNA. Genes of an organisms work together to assist in the development and formation of the organism. It is this similarity that makes humans look like humans rather than a cow or plants (Berg and Singer, 1992).

DNA is shaped like a long double helix. This double helix looks like a spiral staircase. Repeated sequences of phosphate and deoxyribose sugar make up the backbone of DNA. Organic bases attach to the sugar that makes up the backbone. There are four types of these organic bases: Adenine (A), Guanine (G), Cytosine (C), and Thymine (T). These organic bases pair off and make up the stairs of the spiral staircase (Lampton, 1983).

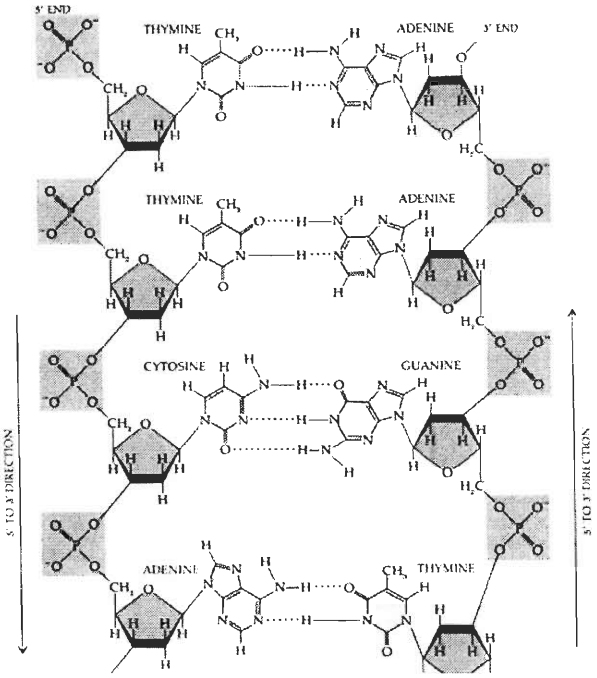

Figure 1.**DNA Chemical Structure**. This represents the chemical components of DNA. Adenine and Thymine are paired together, and Guanine and Cytosine are paired together. The direction of the DNA moves from the 5' end to the 3'end (Raven, 1992).

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A single DNA molecule has approximately three billion of these base pairs. The chemical structure of these base pairs causes only certain bases to pair. Adenine and Thymine will only bond with each other, and Guanine and Cytosine will also only bond with each other. As a result of this bonding system there are only four combinations of bonding that can occur that form the steps of the staircase: T-A, A-T, G-C, and C-G (People V. Castro, 1989).

"Suppose one strand of DNA looks like this:

A-A-C-T-G-A-T-A-G-G-T-C-T-A-G

The DNA strand bound to it will look like this:

T-T-G-A-C-T-A-T-C-C-A-G-A-T-C

Together, the section of DNA would be represented like this:

T-T-G-A-C-T-A-T-C-C-A-G-A-T-C
A-A-C-T-G-A-T-A-G-G-T-C-T-A-G

DNA strands are read in a particular direction, from the top, called the 5' or "five prime" end, to the bottom called the 3' or "three prime" end. In a double helix, the strands start at opposite ends:

5' T-T-G-A-C-T-A-T-C-C-A-G-A-T-C 3'
3' A-A-C-T-G-A-T-A-G-G-T-C-T-A-G 5'

(Brinton and Lieberman, 1994)"

The three billion base pairs that are represented by one DNA molecule are sequenced in specific ways. These sequences can be responsible for producing arms, legs, kidneys, or brain cells.. There are great differences between people due to the fact that their DNA base pairs are arranged differently. The variations between people are called polymorphisms, or anonymous sequence because they occur in different regions of the DNA. Polymorphisms vary in sequence from person to person. Polymorphic DNA regions of base pairs repeat themselves over and over. Base pairs in this Polymorphic region are called Variable Number of Tandem Repeats, or VNTRs. The VNTRs make DNA identification possible (Fridell, 2001). The variations between people are easily seen when the DNA is placed through a series of steps.

DNA Fingerprinting

The chemical structure of DNA is the same in every person. This means that each persons DNA is identical based on the chemical structure. The difference in people's DNA is that each person has a difference sequence of base pairs. Due to the fact that there are millions of base pairs in each person's DNA each person has a unique sequence. By examining these unique base pairs it would be possible to identify a person based

solely on their DNA base pair sequence. However, because of the large number of base pairs in each DNA molecule it would be a wasteful, and a very time-consuming process. Instead of spending so much time determining the whole sequence of millions of base pairs, scientists have created a shortcut. There are repeated sequences of base pairs, and the number of repeats varies between individuals. Instead of determining the whole sequence, scientists are able to analyze a smaller area and still have a unique result.

These patterns do not give an individual "Fingerprint" but rather enable scientists to determine if two DNA samples came from the same person, related people, or non-related people. Scientists then use a small number of sequences that usually vary greatly among people. They then analyze these to obtain a probability of a match between samples.

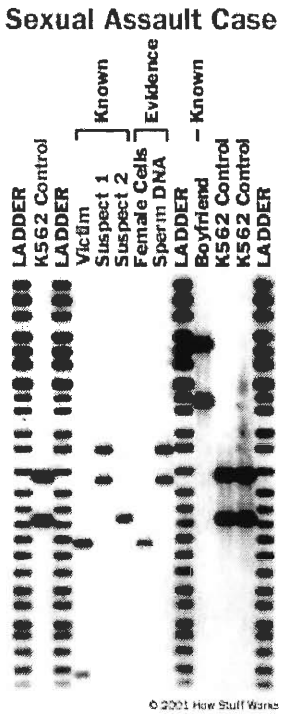

Figure 2. **Sexual Assault Case**. In this diagram two suspects DNAs are compared with the DNA of the Sperm found in the victim. It is seen in the Suspect 1 column that the DNA found in the sperm is the same DNA found at the crime scene. As a result it is concluded that Suspect 1 was the rapist. (Meeker-O'Connell, 2002).

DNA Databank

Due to the large success of DNA fingerprinting testing, the law enforcement community has made steps to create a central DNA databank. Law enforcement has set up a databank similar to the FBI fingerprinting databank. Different than the FBI databank criminals, convicted of serious crimes, are the only people who are entered in the DNA databank. The databank named The National DNA Index System (NDIS) gives forensic lab across the country access to compare their DNA results with results in the databank (Fridell, 2001). "NDIS allows this exciting technology to reach its full potential in solving violent crimes though nationwide information sharing among the 94 public crime laboratories conducting examinations (Fridell, 2001)." All fifty states in the United States of America require certain criminals and offenders to have blood samples taken so their DNA fingerprint can be entered into the databank (Ramsland, 2001). While this databank seems like a great way to find serial offenders, and capture criminals when little evidence is left at a crime scene, it has become controversial. Civil libertarians and defense lawyers argue that DNA fingerprinting is more of an invasion of privacy than the standard ink fingerprinting (Brinton and Lieberman, 1994).

Practical Applications of DNA Fingerprinting

So far the only use of DNA fingerprinting that has been discussed is the use of DNA fingerprinting for criminal identification and forensics. While this is one of the more important uses for DNA analysis, there are other practical applications such as paternity and maternity, and personal identification.

Criminal identification and forensics use DNA that has been isolated from things such as blood, hair, skin cells, semen, or other genetic information. This evidence, which was left at the scene of a crime, is compared with the suspects' DNA through VNTR patterns to determine if the suspect is guilty or innocent. In event that there was a homicide the victims VTNR patterns can be used to help establish their identity. The DNA fingerprint can be taken as DNA used as evidence or directly from the body itself (Fridell, 2001).

As discussed previously, a child will inherit DNA from both parents. As a result VNTR patterns can be used to confirm paternity and maternity. VNTR patterns are so specific that it is possible to reconstruct a parental pattern even if only the child's pattern is known. This type of analysis is primarily used in cases when the father's identity is being questioned. A more complicated case of using this method is to confirm legal nationality, in cases of adoption, or biological parenthood (N.Y. Medical Examiner, 2002).

Lastly, and more futuristically, the use of DNA for personal identification is being questioned. There has been talk of using DNA fingerprints as a form of a genetic bar code for identification. This idea has been discussed but by no means is going to be done in the near future. One of the financial reasons why this method of identification is impractical is the amount of money needed for technology needed to isolate, file, and analyze millions of patterns. Methods used presently such as social security cards, and government picture Ids are more likely to remain the primary use of identification (Brinton and Lieberman, 1994).

The Process of DNA Fingerprinting

As previously discussed in the first section of the chapter, DNA is made of pieces that code for proteins, which control human development. These pieces of information are called Exons. Pieces that do not encode proteins are named Introns. Although Introns are not used for development, they are useful because it has been determined that they contain repeated sequences of base pairs. These sequences are called Variable Number Tandem Repeats (VNTRs). They can contain as few as twenty to as many as one hundred base pairs. The process of DNA fingerprinting is done in a number of steps. "To determine if a person has a particular VNTR a southern blot is preformed, then the southern blot is probed, through a hybridization reaction, with a radioactive version of the version of the VNTR in question. Current analysis use from 7 to 11 different probes. The pattern resulting from this process is a DNA fingerprint (I can not find the Source but I will find it, date). "

RFLP and PCR Methods

Since the mid nineteen eighties two types of testing methods for DNA fingerprinting have been used. One method, which needs a substantial amount of DNA evidence, is Restrictive Fragment Length Polymorphisms (RFLP) analysis. The second method Polymerase Chain Reaction, which is a little less precise, only needs a minute amount (Ramsland, 2001).

The Process of RFLP testing is completed in many steps. In the first step of RFLP testing, the extracted DNA is combined with a restriction enzyme, which causes the DNA to be cut into pieces. Then the fragments, which were cut, are submerged into a gel that separates the DNA fragments by size. This separation is done through electrophoresis

(Ramsland, 2001). Electrophoresis is when an electrical current is applied to the DNA sample. The phosphate groups of DNA are negative, so DNA migrates towards the positive anodes. The shorter the fragment the shorter amount of time it takes to move in the gel. As a result of the electrophoresis the DNA fragments are arranged by size. The DNA is now ready to be analyzed using the Southern Blot, a radioactive probe, and hybridization (Ramsland, 2001).

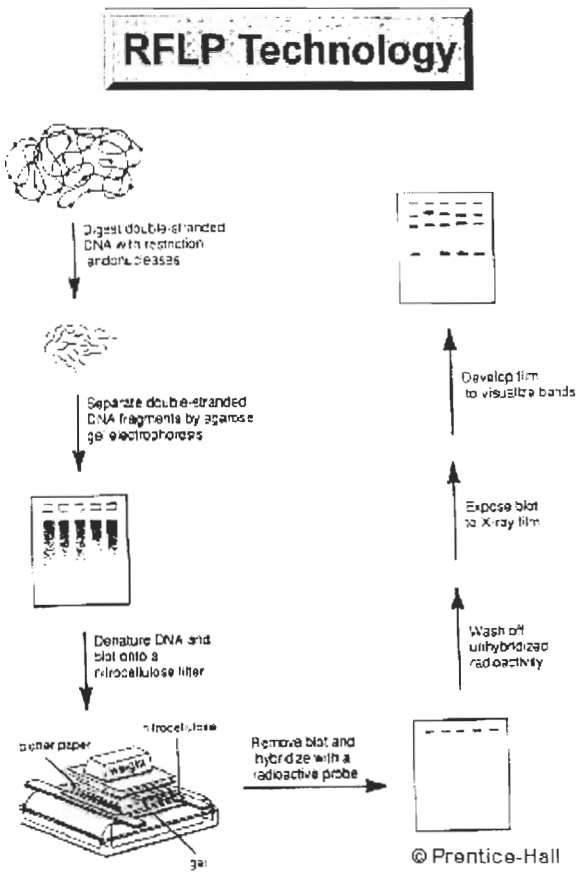

Figure 3. **Steps of RFLP Technology.** This diagram goes step by step to illustrate the sequence of steps required to perform RFLP testing (RFLP Technology, 2002).

An example of a case when RLFP testing was used was in a scenario where a woman was killed and saliva was left on her body from a bite mark. This saliva was compared by RFLP DNA testing to a suspect's blood sample to determine if the suspect was the same person who bit her at the crime scene. The statistical probability was then calculated. Because four fragments of the suspects DNA were identified, the probability of each of those occurring in the general population is then multiplied together to obtain the overall probability (Ramsland, 2001).

After introducing the RFLP testing method, which uses a large amount of blood, or semen, or saliva, the PCR method will be introduced. The PCR method of testing has opened up many cases to the availability of DNA testing because less material is needed for testing. The PCR method is also able to use partially degraded samples that would be useless for RFLP testing. The reason that the PCR method only needs a minute amount of sample is because it functions by mimicking the cell's ability to replicate new DNA (Ramsland, 2001).

Similar to RFLP testing the first step of PCR is extracting the DNA. The DNA is then split into single strands by heating it in a thermocycler. The temperature is then lowered to allow specific primers to anneal to the DNA. The temperature is then raised to 72 degrees Celsius, the optimum temperature of Taq Polymerase to elongate the DNA. This procedure is then repeated over again. Millions of copies of these amplified regions DNA are made (Ramsland, 2001).

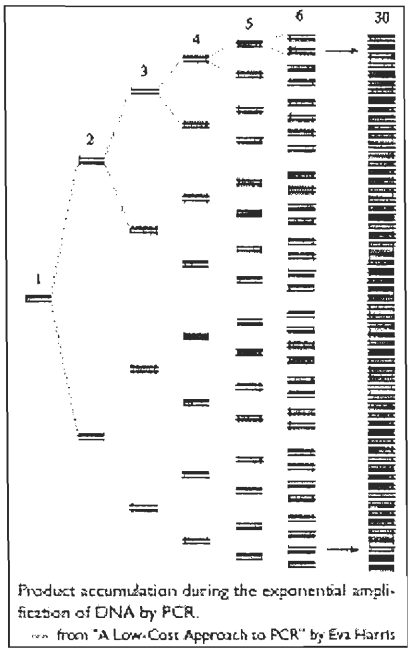

Figure 4. **PCR Multiplication.** In this diagram it is shown through PCR how the DNA is replicated to form new DNA that can be analyzed. "PCR was invented in this country in approximately 1987, and it's a method for amplifying, or multiplying, a single copy of DNA billions of times, so that you can visualize it, and then work with it (Kreisler, 2001)."

Southern Blot

The Southern Blot is one of the key steps of the RFLP analysis protocol. It analyzes the genetic patterns that appear in a person's DNA. The first step in the Southern Blot is to isolate the DNA being analyzed from the rest of the cellular material that is found in the nucleus.

There are two ways to isolate the DNA. The first way to isolate the DNA is to chemically use a detergent to wash away the extra cellular material in the nucleus from the DNA. The second method is done mechanically by applying pressure to the nucleus, which causes the DNA to " squeeze out" following DNA extractions. The second step is to cut the DNA into pieces. Each of the pieces should be a different size. Restriction enzymes are used in order to cut the DNA. Restriction enzymes are usually found in bacteria and cut the DNA at specific sites along the chain. Restriction enzymes always act the same way on DNA and as a result it is possible to make a map of actions that the enzyme makes on a specific set of nucleotides (Brinton and Lieberman, 1994).

The next step is to sort the DNA pieces by size. Gel electrophoresis is the process in which the size separation or fractionation is done. The DNA is poured into a gel such as agarose. Once the DNA is in the gel, an electrical charge is applied. The positive charge is applied at the bottom and the negative charge is applied on the top. The DNA pieces are attracted to the bottom of the gel because the DNA has a slight negative

charge. The smaller the piece of DNA the more quickly and father down the gel the piece will go. The DNA will then be separated by size because the small pieces will be near the bottom while the larger pieces will be closer to the top of the gel (State v. Pierce, 1992).

The fourth step of the Southern Blot is the denaturing of the DNA. The denaturation is done though heating or chemically treating the DNA while it is in the gel. The last step is to blot the DNA. A piece of nitrocellulose paper is applied to the gel, and then the gel is baked to permanently attach the paper to the DNA (Brinton and Lieberman, 1994). The Southern Blot has been completed and ready for analysis.

Making a Radioactive Probe

A probe is strand of DNA that is radioactive and used to find specific sequences in a Southern Blot. The DNA that needs to be made radioactive is placed into a test tube.

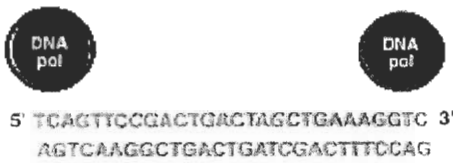

Figure 5 **Step 1 of Making a Probe.** The DNA strand is double sided. It is ready to be placed into a test tube to be made radioactive (Brinton and Lieberman, 1994).

The DNA is nicked or horizontally broken along the strand. While nicking the DNA, individual nucleotides are added to the nicked DNA. One of these nucleotides should be radioactive (Brinton and Lieberman, 1994).

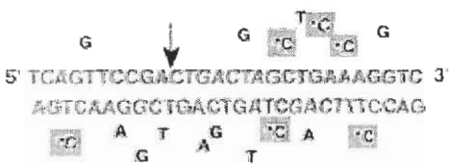

Figure 6 **Addition of nucleotides.** The individual nucleotides are added to the nicked DNA. The nucleotide is Cytosine and is radioactive (Brinton and Lieberman, 1994).

DNA Polymerase is added to the nicked DNA and the individual nucleotides. DNA Polymerase is an enzyme that repairs DNA by forming hydrogen bonds between nucleotides on broken DNA pieces. The nucleotide needs the Polymerase to form a stable and complete base pair. Now that the DNA Polymerase has been added it will immediately start repairing the DNA working from the 5' end and moving towards the 3' end (Brinton and Lieberman, 1994).

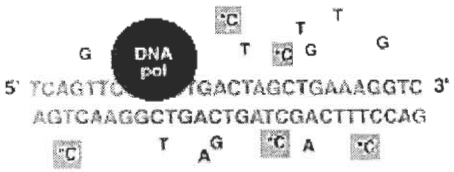

Figure 7. **Addition of DNA Polymerase**. At this point of making the probe the DNA Polymerase is added to the nicked DNA (Brinton and Lieberman, 1994).

As the DNA Polymerase is repairing it is also destroying all of the existing bonds that comes in front of it. It places the new nucleotides behind it as it works. When the Polymerase reads a G on the lower strand it places a radioactive C base in the new strand to form a complete and stable base pair. As a result of the Polymerase, the nicked DNA is repaired and the strand becomes radioactive due to the addition of radioactive C bases (Brinton and Lieberman, 1994).

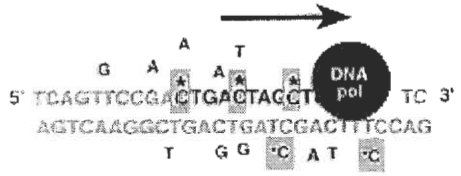

Figure 8. **Becoming Radioactive**. The DNA Polymerase reads G and replaces the nicked area with a radioactive C making the strand radioactive (Brinton and Lieberman, 1994).

Since the point of this procedure is to have a radioactive probe, the DNA strands need to be split. Heating the nicked DNA splits the two strands. This splits the two DNA strands apart leaving two single stranded pieces, one radioactive and one non radioactive. The radioactive strand is called a probe and ready to be used (Brinton and Lieberman, 1994).

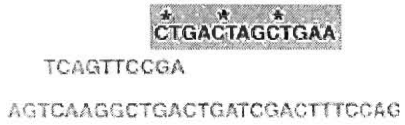

Figure 9. **Creating a Probe**. The DNA splits into two creating one separate radioactive probe that is shown in the diagram as blue (Brinton and Lieberman, 1994).

Hybridization Reaction

The binding of two genetic sequences is called hybridization. The hybridization reaction is the process where the probe binds to the Southern Blot. The probe only binds to the Southern Blot if the DNA sequence on both match. Due to the hydrogen bonds between base pairs the binding occurs.

DNA must be denatured before it can be hybridized. This denaturation was completed during the last process of creating a radioactive probe. As a result of the denaturing the single stranded DNA has bases that are available for hydrogen bonding. The single stranded radioactive probe is then used to detect the denatured DNA if it contains a similar sequence to one on the probe. The probe, saline, and the denatured DNA are placed in a plastic bag. The bag is then shaken and if the probe finds a fit it will bind to the DNA (Brinton and Lieberman, 1994).

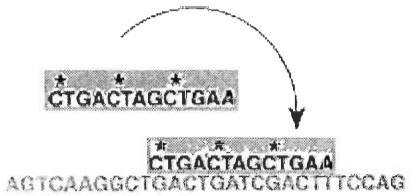

Figure 10. **Probe Finds a Fit.** If the probe fits a fit on a new strand of DNA it will bind to it becoming double stranded again. (Brinton and Lieberman, 1994).

The probe does not need to find an exact fit in order to bind. The worse the fit, the fewer the number of hydrogen bonds that exist between the probe and the denatured DNA. The amount of binding that occurs when there is not an exact fit can be altered by raising the temperature during the reaction, and by the amount of saline added to the mixture.

An X-ray is then taken of the Southern Blot after the radioactive probe has bonded to the denatured DNA on the paper. Only areas the radioactive probe binds will appear on the film. The results allows researchers to identify the occurrence and frequency of the pattern contained in the probe. This resulting pattern is called the DNA Fingerprint (Brinton and Lieberman, 1994).

Problems with DNA Fingerprinting

While a fingerprint is thought of being completely unique to each individual, the name DNA fingerprint often misleads people. A DNA fingerprint is not a unique system of identification. The VNTR pattern of a person is not unique, yet it often presents a high probability of that person being the person whose VNTR was being investigated. The probability for each case is different based on the evidence. A probability of 1 out of 30 million would be enough to prove that this person was probably the same one whose DNA was tested. A probability of 1 out of 50 is not a good enough percent to prove based

solely on the DNA evidence. To increase the probability of a DNA fingerprint, rare VNTRs or combinations of VNTRs are used (Brinton and Lieberman, 1994).

CHAPTER TWO : DNA FORENSICS

Introduction

The word 'forensic' is defined as "relating to or dealing with the application of scientific knowledge to legal problems". (Merriam-Webster, 1996) DNA Forensics begins at the scene of the crime, where both subtle and overt biological traces may be collected to be used as evidence in a court of law. If properly collected and analyzed, these clues will yield their constituent DNA and establish a link between a crime and any involved individuals.

Evidence Collection and Storage

It is the crime scene investigators who are responsible for finding and isolating these biological samples, ensuring they are both physically and legally pure. Forensic DNA evidence is threatened by three problems:

- Degradation
- Contamination
- Broken or weak 'link' in chain of evidence.

Initially, evidence must be carefully stored and collected so that the DNA is preserved. More importantly, the evidence must be collected with sterile materials and remain isolated. Finally, every action involving a sample must be documented in the evidence log to show a proper chain of evidence from the crime scene to the courtroom.

At the crime scene, proper techniques must be used to successfully meet these requirements. All crime scene personnel should wear sterile clothing, use gloves, and clean forceps where necessary to prevent any outside material or biological traces to contaminate evidence or the scene. Also, it is crucial to include a control sample with each item that has been subjected to all collection methods, but not exposed to the sample. This allows the lab to document and rule out any incidental corruption that may be later corrected. (Kramer, 2002)

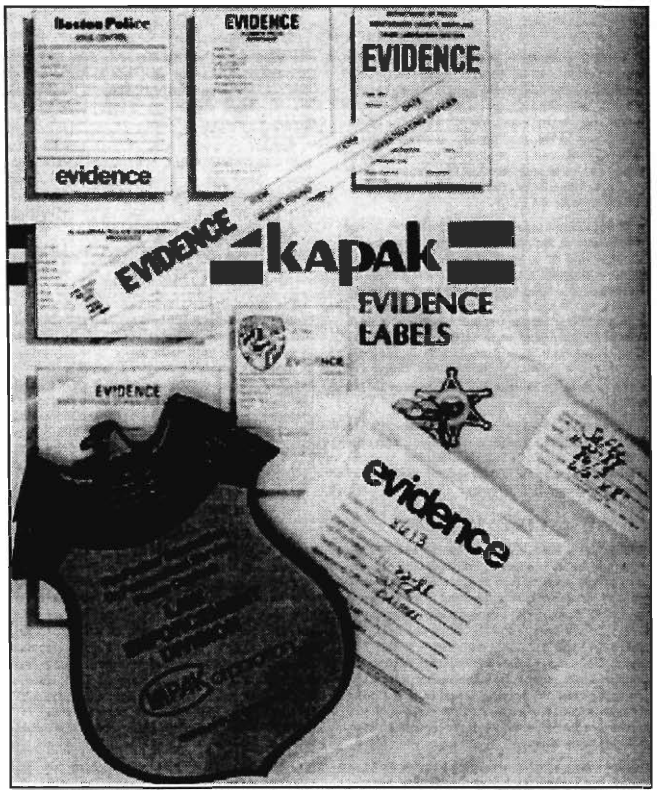

Figure 11 - Evidence Labels and Forms
(Office of Technology Assessment, 1990)

Collecting DNA evidence from a crime scene involves removing the specimen and allowing it to air dry, before packaging and documentation. Small objects should be collected whole. Evidence on larger objects should be physically removed (cut off) or transferred via swabbing with sterile cotton. Dried stains may be transferred via the usage of distilled water to a sterile cotton medium. (Federal Bureau of Investigation, 1999)

Hair samples must be handled carefully with forceps so that the root at the end is not damaged. If possible, hair should be taken directly from a corpse to leave the root intact. Unlike other samples, tissue samples should be placed in a clean, airtight plastic

container and frozen (without any preservative such as Formulin or Formaldehyde). Bones should be chosen from long bones (ribs, femur, etc) and a sample 3 to 5 inches in length removed and frozen. (Federal Bureau of Investigation, 1999)

Samples thought to contain DNA evidence should be stored in a cool and dry place, to avoid damage from moisture and ultraviolet radiation (e.g. sunlight). Other than bones and tissue, clean paper or sealed envelopes are the preferred container. This allows the sample to breathe, preventing a buildup of moisture. Plastic is to be avoided, since it tends to both contain moisture and allow ultraviolet radiation. Proper storage will prevent samples from deteriorating prior to analysis. (Kramer, 2002)

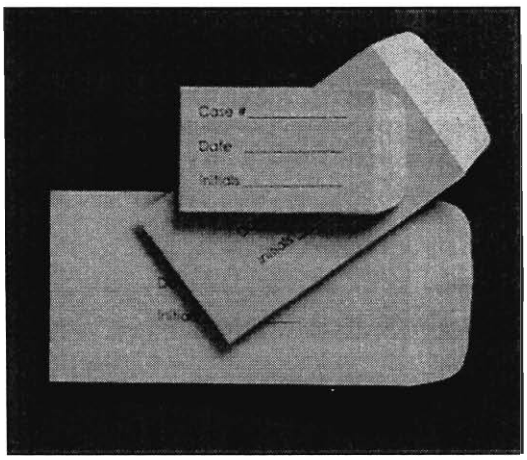

Figure 12 - Evidence Envelopes
(Evidence Collection & Protection, 1998)

DNA profiling (especially PCR testing) is extremely sensitive to outside contamination, therefore it is essential that all evidence at a crime scene be collected quickly and protected. Rubber gloves should always be used and changed often. Any individual returning to a crime scene must don a fresh set of sterile clothing to isolate the scene. Also, investigators should take care of personal contamination; a stray sneeze or clump of dandruff could completely invalidate a crucial genetic link. (National Institute of Justice, 1999)

Each piece of evidence must be properly documented in a methodical fashion from the very outset of collection. Any sample at a crime scene must include the following information:

- Time and Date
- Subject's name
- Location
- Collector's name
- Case and Evidence identification numbers

Proper documentation is essential to providing the background necessary to introduce a sample as evidence in a court of law. (Federal Bureau of Investigation, 1999)

In addition to stringent standards of isolation, it is essential that an entire physical sample be harvested for analysis. Advances in the usage of PCR testing allow even the most minute sample to yield a solid profile. The following biological materials contain DNA, in order of highest to lowest content:

- Semen: oral, rectal, and vaginal swabs, and clothing stains.
- Blood: stains on objects or clothing.
- Saliva: cigarette butts, ski masks, envelopes, glasses, and chewing gum.
- Hair: on victim or about scene.
- Urine/Feces: at scene.

Objects in contact with bodily fluids or human waste will have traces of DNA suitable for profiling. Any item suspected of containing DNA should be submitted to a lab for analysis. Also, the chemical reagent Luminol is often used at a crime scene to determine traces of obscure or concealed blood. Luminol is sprayed upon the area. Where it contacts blood it reacts, giving off a luminescent glow visible in the dark. (Kramer, 1999)

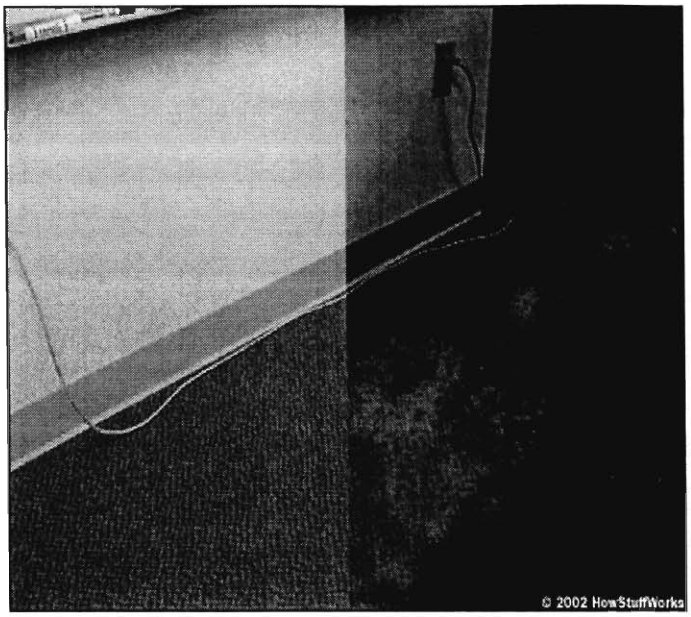

Figure 13 - Luminol Test Reveals Hidden Bloodstains
(Harris, 1998)

It has been determined that blood containing Luminol may be used effectively for PCR DNA profiling without adverse effects. This opens up Luminol as a powerful tool for locating DNA evidence without compromising it in the process. (Della Manna and MontPetit, 2000)

Sample Preparation

Using these physical samples from the crime scene, groups of human cells are collected. The DNA used for the sample is extracted and collected. Normally, regular human nuclear DNA (nucDNA) is used. However, where a sample is old and nucDNA is deteriorated, Mitochondrial DNA (mtDNA) is used. Both nucDNA and mtDNA are extracted via the same process, allowing the DNA profiling process to distinguish the difference between them. (Isenberg and Moore, 1999)

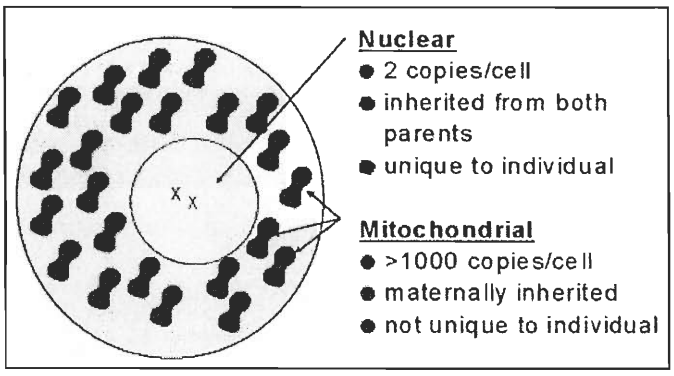

Figure 14 –Mitochondrial vs. Nuclear DNA
(Isenberg and Moore, 1999)

In the laboratory, these cells are ruptured, subjected to lysis via introduction of a detergent such as Sodium Dodecyl Sulfate. When the cells lyse, their contents are released. (Sheindlin, 1996)

This cellular miasma must be further processed to separate the DNA. The proteins in the mixture are broken down through the addition of an enzyme such as Proteinase K. Now, the DNA itself may be removed via one of two processes: either precipitation induced by alcohol or ultrafiltration through a specialized membrane. Either process elicits the same result. (Sheindlin, 1996)

DNA Profiling

The isolated DNA sample can now be profiled using one of the methods previously described. Any difference determined by the profile will immediately rule out a match between two samples. If a match is determined across all of the tested loci, then the results must be further interpreted before being presented as evidence.

Statistical Analysis

These matches have no meaning without applying statistical analysis to determine the significance of these particular loci sharing the same values between two samples. It is through these statistical methods that the link between matching some number of alleles and showing legal proof is created.

A DNA profile is really a small sample of several special locations on what is a massive human genome. The ability of this sample to speak for the whole of the genetic codex relies on identifying the uniqueness within the population of each allele sampled.

We cannot juxtapose the entire genetic sequence, so we must rely on statistics to summarize. It must be demonstrated that this profile is highly unlikely to match others within the population. The odds of a random individual also having this same DNA profile must be calculated. To accomplish this, the loci within the profile must be cross-referenced with a database of population genetics.

A statistical model is built to represent the actual population and its genetics. To build this model, several simplifying assumptions must be made. We must assume that the population maintains a consistent genetic diversity across generations. This assumption is referred to as Hardy-Weinberg Equilibrium. Given the relative population frequency of an allele, we can calculate the probability of a random individual having all the alleles present in our DNA profile through use of the statistical principle called the Product rule. (National Academy of Sciences, 1992)

The product rule states that for a given series of independent events, each with their own probability of occurring, the probability of *all* of these events occurring is the product of their individual probabilities. The key to this principle is ensuring that the events are actually independent.

For a DNA profile, it must be ensured that loci are chosen such that none are found on the same chromosome. The presence of each allele must not be contingent upon the presence of any of the others. This is referred to as Linkage Equilibrium. (National Academy of Sciences, 1992)

In the simple model, the probability of another individual having the same DNA profile as our sample will also be the product of the probability (population frequency) of each allele at a given locus. Unfortunately, the reality is not this simple.

The population of the United States is extremely diverse, and not necessarily evenly distributed genetically. The scientific community raised the issue of the Wahlund effect, referred to as population substructure. The existence of substructure within the population is defined as the potential for several ethnic or racial groups to have dramatic variations in frequency of particular genetic characteristics. Random population sampling would likely not reflect this in their attempt to characterize the whole of the population. The argument against the simple population model contends that the Hardy-Weinberg Equilibrium does not hold for the population. This claim stems from the belief that people often select whom they mate with based on particular criteria. This would invalidate the conditions of Hardy-Weinberg equilibrium and cause a complex ethnic substructure within the population. (Hartl and Lewontin, 1991)

The criticism of the model was answered with a methodical reorganization of the statistical methods used to support population sampling. To answer their critics, the new methods are built to account for substructure in a population. It is important to note that these DNA profiles are used as legal evidence. Due to this, the burden of proof resides on the prosecution. Therefore, even if the exact population characteristics are not known, the estimates are weighted in the favor of the defendant (against a DNA match). This methodology employs the Ceiling Principle. (National Academy of Sciences, 1992)

The Ceiling Principle calls for the *overestimation* of allele frequency, to accommodate the potential for substructure within a population. The new methods urge a deliberate attempt to sample from each subgroup within a population. The group that shows the highest frequency of an allele (above a minimum 5%) sets the frequency for the entire population. This approach forces the systematic overestimation of the

frequency of each allele. The Product rule may then be correctly applied, as previously described. (National Academy of Sciences, 1992)

Conclusion

For a DNA profile to serve as evidence in a court of law, all crime scene evidence must be processed and documented carefully. Any number of a wide variety of physical evidence may contain genetic traces. When evidence is collected correctly, it may then serve as the genetic seed for a DNA profile. A matching DNA profile becomes powerful and persuasive legal evidence when verified through statistics and population genetics.

CHAPTER THREE: LANDMARK DNA COURT CASES

County Court, Albany County, New York

The PEOPLE of the State of New York
v.
George Wesley, Defendant
Jul 15, 1988

George Wesley, the defendant, was charged with burglary in the second degree and murder in the second degree on July 15, 1988. Due to the fact that bloodstained clothing was retrieved from the defendant, the People wanted to have a blood analysis of the bloodstains. The people also wanted to compare the victim's DNA, Wesley's DNA, and the DNA found on the victim. In order to compare the DNA found on the victim with Wesley's DNA, the People moved for an order to request an extraction or blood and hair from the defendant. In order to determine if the blood and hair should be taken from the defendant, the purpose and admissibly of this evidence needed to be stated (People v. Wesley).

The results of DNA fingerprinting would only be admissible in court if the testing was reliable and had gained acceptance in its scientific community. The defense argued that Lifecodes, the laboratory who was preformed the testing, did not have quality controls and therefore could not assure the reliability of the results. The defense also argued that the manner in which Lifecodes formulated it population studies were also inadequate. The prosecution introduced Dr. Roberts who was a Assistant Director for research at another Laboratory. Dr. Roberts who was respectable and well educated in this field of research investigated the procedure of testing at Lifecodes. He first stated that all of the technology and principles that Lifecodes uses in DNA fingerprinting testing

are valid and accepted by the scientific community. He then went on to explain that Lifecodes has a well established quality of controls to insure accurate results. It was also stated that Lifecodes used the methodology used in matrices was also accurate, and as a result the formulation of the probability estimates were valid. As a result a blood extraction and hair samples were required of George Wesley (People V. Wesley). This case gave great support to the use and technology used in DNA fingerprinting. Due to the descriptions needed to prove that Lifecodes was performing the tests accurately and with controls, the public was made more aware of the use of DNA fingerprinting. This case helped future cases prove that DNA fingerprinting is valid as long as certain standards are applied to the testing laboratory.

District Court of Appeal of Florida
Fifth District

Tommie Lee ANDREWS, Appellant
v.
STATE of Florida, Appellee
Oct 20, 1988

Tommie Lee Andrews, the defendant, was convicted in the Circuit Court of Orange County of sexual battery, aggravated battery, and armed burglary of a residential dwelling. Upon appeal, the District Court stated that the genetic fingerprint evidence was admissible and thus the punishment was justified and appropriate. Andrews was convicted of an early morning burglary on February 21, 1987. The victim awoke to someone jumping on top of her and holding a razor blade to her neck. The intruder, who was later found to be Andrews, threatened the victim that if she saw his face he would kill her. In a struggle for freedom the victim was cut on her face, neck, feet, and legs. The

intruder then raped the victim before fleeing the premises with her purse. A crime scene investigator testified that on the day following the attack, one of the windows of the victim's house was open but the screen was missing. The screen was then found on the ground and was tested for fingerprints (Andrews v. State).

After the attack a physical examination was administered to the victim to collect any evidence of the rape. As a result of the examination semen was found inside of the woman. The analysis of this semen was performed and the intruder was determined to have type O blood. Like the majority of the population, the intruder was a "secretor" which means he secretes blood in his saliva and bodily fluids. Since the victim was not a secretor the blood taken from the vaginal swabs was concluded to be the intruders. Lifecodes Corp analyzed this blood. The State presented the DNA print as evidence linking Andrews to the crime. Lifecodes concluded that the blood taken from the vaginal swab and Andrews was a match. The percentage of the population that would have the same DNA bands as Andrews would be 0.0000012%. The fingerprints lifted from the screen that was found on the ground the day after the attack also matched Andrews. Both of these findings convicted Andrews of aggravated battery, sexual battery, and armed burglary (Andrews v. State). The admissibility of this DNA fingerprint evidence greatly impacted future cases. Prosecution lawyers were now given the ability to enter DNA fingerprints as valid evidence.

The People of the State of New York
v.
Joseph CASTRO, Defendant
Aug 14, 1989

The defendant Joseph Castro was accused of two counts of murder in the second degree. On February 5, 1987, it is alleged that Castro stabbed twenty-year-old Vilma Ponce to death. Ponce at the time was seven months pregnant, and with her two year old daughter. A wristwatch, believed to be worn at the time of the murder, was seized upon Castro's arrest. The wristwatch was noted to have what appeared to be bloodstains, which is why it was confiscated. The defendant explained that the bloodstains were his own. The People's desire to introduce DNA identification tests in the trial was based on the bloodstains on the watch. The People wanted to prove that the blood on the wristwatch was in fact not the defendants but rather the blood of Vilma Ponce (People v.Castro).

The Supreme Court, Bronx County, Sheindlin J,. accepted that the scientific tests were preformed accurately, and DNA identification evidence admissible. Lifecodes, the testing laboratory in Valhalla, New York, did substantially perform scientifically accepted tests regarding evidence of exclusion. The reason that the DNA identification evidence was deemed inadmissible was due to the fact that Lifecodes failed to use generally accepted techniques to obtain reliable results regarding evidence of inclusion. This meant that Lifecodes laboratory failed in several respects to the use of generally accepted scientific techniques and experiments to obtain results within a reasonable degree of scientific certainty (People v. Castro). Due to the inadmissibility of evidence in this case, future cases that include DNA fingerprinting will create standards for the testing of DNA fingerprinting.

United States Court of Appeals
Eighth Circuit
UNITED STATES of America, Appellee
v.
Matthew Sylvester TWO BULLS, a/k/a/ Matthew Sylvester Two Bulls, Jr. Appellant.
Decided October 31, 1990

Matthew Sylvester Two Bulls was charged after allegedly raping a fourteen-year-old girl on the Pine Ridge Indian Reservation. The FBI laboratory examined the girl's underwear that was seized from the victim after the attack. The FBI used DNA profiling to examine the underwear and isolated the semen stain that was found. It was concluded that the semen on the underwear had a high probability of being Two Bulls *(US v Two Bulls)*. As a result, Two Bulls was charged and convicted of aggravated sexual abuse, and sexual abuse of a minor. Upon conviction, the defendant moved for an appeal claiming that the court did not examine the standards of the DNA analysis.

Two Bulls claimed the court motioned to allow the DNA evidence after hearing only one witness. The witness established that DNA profiling or fingerprinting was generally accepted by the scientific community and could be presented in trial. Two Bulls argued that the court only looked at the admissibility of DNA fingerprinting and neglected to investigate the process in which the test was being done. Two Bulls introduced the case involving Castro. In this case there was a three step test used to determine the admissibility of the DNA evidence. The three aspects of the test were, if the theory of DNA fingerprinting is accepted by the scientific community, if the methods used to do DNA fingerprinting are accepted by the scientific community, and whether or not that laboratory that is doing the DFNA analysis is using these methods. It was ordered that since none of the aspects were looked at before DNA evidence was entered in Two

Bulls' case, a new trial would be granted. In the new pretrial, not only was the three step test to be used, but also an addition two steps was added. The additional two steps are "whether the evidence is more prejudicial than probative, and whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial *(US v. Two Bulls)*." The court rules that the DNA fingerprinting evidence was admissible and valid. As a result, Two Bulls was again convicted of aggravated sexual assault and sexual assault of a minor. As seen in this case, the defendant relied on another case that used DNA fingerprinting standards to create a similar standard of admissibility. Cases that involve DNA fingerprinting serve as supportive evidence on both sides, and as a result, help increase the accuracy and testing of DNA fingerprinting.

Supreme Court of South Dakota
State of South Dakota, Plaintiff and Appellee
v.
Will D WIMBERLY, Defendenat and Appellant
Argued November 26, 1990
Decided March 20, 1991

On the 26th of November nineteen hundred and ninety, Will D Wimberly was charged with first-degree rape. On February 18, 1989, around 8 in the evening, Wimberly and two other men picked up M.S. at her grandmother's house and went driving. M.S. was a fourteen-year-old eighth grader and friends with the other two men with Wimberly. While driving the three men and the fourteen-year-old girl drank beer and gin. The foursome went ot one of the two men's trailer. M.S. remembers having consensual sexual

intercourse with one of Wimberly's friends. M.S. remembers being pushed back into the bedroom of the trailer by another man, who then raped her. M.S. asked to go to the bathroom to put on her clothes. Upon returning from the bathroom Wimberly then pushed her out the back door of the trailer. M.S. went to another trailer and asked for the police to be called. Before the police returned she had passed out and was then taken to the hospital. At the hospital a rape sex crime kit was used to gather evidence of the attack. M.S. identified Wimberly in a photographic line up. The DNA evidence taken from the rape kit proved to have semen of Wimberly and the other man she had consensual intercourse with. Wimberly was then convicted of rape in the first degree (State v. Wimberly).

Wimberly appealed the conviction of rape in the first degree. Wimberly's main argument was the fact that since there was such a long time delay between the blood sample being taken and the DNA analysis, the DNA could have been tampered with. The Defense argued that there was no record of the DNA being transported between the police and the laboratory. Responding to statement, the prosecution described the process in which the blood was taken from Wimberly and the records that were taken of it to insure its validity. As a result the court ordered that the DNA had been properly taken and tested, and dismissed Wimberly's argument (State v. Wimberly). This specific case was a learning tool for other cases that involved DNA fingerprinting. This case taught that record regarding the custody of the DNA should be kept to insure the validity of the sample.

Appellate Court of Illinois

Fourth District.

The PEOPLE of the State of Illinois, Plaintiff-Appellee
v.
Reggie E. MILES, Defendant-Appellant
Aug 6, 1991

On August 6th nineteen hundred and ninety one, Reggie E Miles was convicted of two counts of home invasion, five counts of aggravated criminal sexual assault, one count of criminal sexual assault, one count of aggravated unlawful restraint, one count of armed robbery, and two counts of residential burglary. G.S., the victim, awoke on November 3rd 1987 by a noise that she heard in the house. As she was trying to flee from the house a man opened the front door and knocked her to the ground. The man she described as African American, and approximately 5'10 and 160 lbs. Due to the fact that she was not wearing her glasses she could not be more accurate. The intruder obtained a kitchen knife and for the next six hours threatened G.S.'s life eighth times. He sexually assaulted her twice and then struck her at least five times. He then drove her to an automatic teller and forced her to withdraw two hundred dollars from her account. After withdrawing the money they returned home where he found her account passbook. He then took her back to the bank and with a knife between her legs forced her to withdraw all of her money. The intruder then threatened to kill her and G.S. pleaded for her life. Suddenly the intruder jumped from the car and fled. The victim's cars, along with items in the house were processed for fingerprints. A sexual assault kit was used to collect and semen samples from the victim. There was a match between the DNA taken from Miles' blood sample and the sample from the bed sheets (People v Miles).

Upon conviction Reggie E. Miles appealed. Miles claimed that the DNA evidence should not have been accepted. The court denied his request stating that they had produced enough evidence proving the admissibility and validity of the DNA fingerprinting. The court proved that the scientific community accepted DNA fingerprinting and the techniques used in the laboratory produced a reliable result. Based on the type of analysis preformed, the semen stain also had a one in 300,000 chance of being somebody's other than Miles (People v. Miles). In this case an appeal was not granted because of the court's standards in admitting DNA evidence. In the future other cases that involve DNA profiling will look back on this case for structure on how to test for the admissibility of DNA fingerprinting.

County Court, Westchester County, New York

The PEOPLE of the State of New York
v.
Morteza Mohit, defendant
Jan 9, 1992

Morteza Mohit was charged for rape and sexual abuse on January 9th 1992. Mohit was an Iranian born physician who was practicing in New York. He allegedly raped and sexually abused a patient during a routine office visit. A sexual assault kit collected evidence of the attack a few hours after the incident. A vaginal swab that was collected using the kit, contained semen. Along with the vaginal swab, blood was taken from Dr. Mohit and the victim and then sent to the FBI Laboratory. The DNA from the semen was extracted and compared with the DNA of the defendant. The laboratory determined that there was a match (People v. Mohit).

The defendant moved to exclude the DNA analysis of the semen and blood samples. The Defense argued that Dr. Mohit did not fit into the general population in which the DNA analysis is compared to. It was argued that the defendant was a Shiite Muslim, and in the Muslim religion it is very common for inbreeding to occur. The defendant's ancestors over the past five generations all remained in the same town. The inbreeding between them was usually between first cousins. The Defense argued that the FBI assumes the DNA sample have been taken from a person where inbreeding does not occur. As a result of this standard, Dr Mohit's DNA evidence would not be accurate. The Prosecution explained that the FBI protocol for declaring matches between samples is accepted by the scientific community, and that inbreeding would not affect the result of the test. While the DNA proved to be a match in this case, the probability of the match occurring in the general population was hard to calculate. The defense argued that, due to the unusual genetic inbreeding circumstances, the technique used to generate a probability of the match occurring in the general population would not be as accurate. The Prosecution then limited the probability to being less than 1 in 100,000. As a result of the probability being approximated, the Defense's effort to have the evidence removed was denied and Mohit was found guilty (People v. Mohit). As a result of this case, not only did DNA fingerprinting become more acceptable in the court of law, but it also broadened the number of different cultures that could benefit from this new technology.

Supreme Court of Ohio

The STATE of Ohio, Appellee
v.
PIERCE, Appellant
June 2, 1992

On June 2nd 1992 Louis Pierce Jr. was charged and later convicted of two counts of rape, and one count of kidnapping. Pierce was accused of three separate attacks on women in the Delaware area. The first alleged attack occurred on January 4th , 1988 when a high school student was raped at knifepoint on her way to school. After the attack a rape sex crime kit was preformed to collect any evidence. The victim described the man as half black and half white, but could not pick him out of a photo array. The second attack was on May 2nd , 1988 when another high school student was raped at knifepoint while she was sunbathing at the State Park. A rape sex crime kit was used at the hospital, in which samples of evidence were taken from the victim. The victim was able to identify the man as Pierce in a photo array. On June 6th , 1988 the third and last attack occurred. The third victim was accosted by a man on the street that she later identified as Pierce. The victim explained Pierce threatened her with a gun. The victim struck Pierce and was able to break away as Pierce had a vehicle waiting for them to get into. All of these cases and their charges were consolidated into one case. Louis Pierce Jr. had blood taken while in prison to be analyzed with the rape sex crime kit (State v. Pierce).

Pierce and his trial lawyer argued the admissibility of the DNA forensic evidence. They claimed that at the time of the trial DNA forensic evidence had not been accepted by the scientific community and therefore was inadmissible. They also denied any standards of guidelines had been used regarding the DNA evidence. The court overruled the motion by explaining that it was up to the jury to determine the weight and

importance of the DNA evidence. The Prosecution in trial explained the background of DNA, and the process in which it is analyzed. The Prosecution continued to use other court cases such as *Andrews v the State* (see earlier case, 1988) to show the acceptance of DNA evidence in court. As a result of the DNA evidence, Pierce was convicted of two counts of rape and one count of kidnapping (State v. Pierce). As seen in this case, previous cases that have accepted or rejected DNA evidence play an important role. The Defense or Prosecution can use past cases to support or reject the use of DNA fingerprinting.

CHAPTER 4 – SENSATIONAL DNA COURT CASES

Introduction

The use of DNA in America's court system has not escaped the public or media's eye. Several famous cases have shaped the way the public views the technology and forms an opinion on the admissibility of evidence. As new DNA technologies lead to more accurate findings, the strong desire to solve modern mysteries with DNA fingerprinting has forced several respected and notorious historical figures back into the headlines from past their graves.

First this chapter will discuss the most sensational DNA court case in recent history, the O.J. Simpson criminal trial. The national broadcast of the trial brought DNA fingerprinting into America's living rooms – DNA was no longer a mysterious scientific phenomena but a modern crime solving tool subject to scientific and investigation standards. Following are several more modern cases, mostly outside the courtroom, involving identification of bodies and bloodlines. The desire to find living descendants drives the Grandmothers of the Plaza while attempting to bury loved ones drives families of Bosnia and World Trade Center bombing victims. Lastly, this chapter covers historical figures and the new details being discovered about their lives and how they died. These new details are helping modern day families set the facts straight about their ancestors including Thomas Jefferson and Albert DeSalvo.

O.J. Simpson

On June 15, 1994, O.J. Simpson and longtime friend A.C. Cowlings led California police on a slow-speed highway chase. The chase was highly televised as was almost every other aspect of the case including press conferences, motions, hearings and the entire trial itself. The case replaced the Lindbergh baby kidnapping as the trial of the century, and "more than 100 witnesses would be called, 1,000 exhibits of evidence would be presented and nearly 9 months would pass … and the outcome would hinge largely on the handling of DNA fingerprinting evidence obtained from blood found at the scene of the crime and on the clothing, driveway and car of O.J. Simpson." (Nickell and Fischer, 1998, pg 205; Fridell, 2001, pg 49)

Simpson was arraigned on double murder on June 15, 1994. Simpson's second ex-wife Nicole Brown and friend Ronald Goldman were stabbed to death in the walkway of Brown's Bundy Drive townhouse on June 12, 1994. Blood splatter from the crime stained the concrete walkway and the gate to her backdoor entrance. Simpson was unaccounted for during the murders and quickly left his Rockingham estate for a flight to Chicago that night.

Nicole Brown had had a long history of domestic abuse at the hands of Simpson, so much so that Nicole was on a first-name basis with several LA area 911 operators (Lee and Labriola, 2001, 190). Simpson would often track her to her house and demand her back, and then becoming violent after rejection.

Ronald Goldman seemed to be "a classic example of a person who was at the wrong pace at the wrong time." (Lee and Labriola, 2001, pg 196) A waiter at Mezzaluna Trattoria, Goldman had struck up a friendship with Brown during her many trips to the

spot. Brown held a reception for her daughter's dance recital at the upscale Italian restaurant. Brown's mother had forgotten her reading glasses and Goldman had promised to deliver them. The glasses were found at the murder scene near Goldman in a white envelope (Lee, Labriola, 2001, pg 197).

Minute by minute detail about the investigation of Simpson is available in many newspaper articles, journals, magazines and books on the subject. Rather than give all details of the investigation, here we choose to discuss the DNA evidence only.

The Evidence

There were six major pieces of DNA fingerprint evidence in the Simpson case. The most important evidence included (1) a bloody glove found between Brown and Goldman, (2) a bloody glove found behind Simpson's house, (3) 3 blood stains matching Simpson at the crime scene, (4) 5 blood stains matching Simpson leading away from the crime scene, (5) small blood stains on the Ford Bronco parked outside Simpson's estate, and (6) a pair of bloody socks which matched Simpson and Brown (Fridell, 2001, pg 49).

The bloody glove found at Simpson's estate (2) was the most famous piece of evidence. One bloody glove was found between Brown and Goldman at the murder scene. A second, right-handed matching dark brown glove was found in a side alley between Simpson's house and the fence (Nickell and Fischer, 1998, pg 206). Down this path were the guest quarters where Arnelle Simpson and Kaito Kaitlin were living. Kaito Kaitlin had claimed to hear a bump outside his suite around the time Simpson was seen emerging from the driveway near the alley by the limo driver (Nickell and Fischer, 1998, pg 206).

The prosecution claimed Simpson had ditched the glove in a rush to dispose of the evidence. To support their theory they pointed to O.J. Simpson's cut finger. The cut on his left hand middle finger matched the location of a cut in the glove found at the crime scene. The prosecution claimed that the small droplets of Simpson's blood leading away from the crime scene were a result of the cut (evidence 4).

The blood droplets leading away from the murder scene were DNA positive for Simpson with the likelihood of it belonging to someone else being only 1 in 170 million (Lee and Labriola, 2001, pg 208). As a defense, Simpson stated he had cut his finger on a glass he broke during the phone call informing him of Brown's death. The blood droplets must have been planted evidence, as was the bloody glove.

Next, there were small blood droplets on the outside door, dashboard and steering wheel of Simpson's white Ford Bronco (evidence 5). This evidence was probably more troubling to the Prosecution than it was damning to Simpson. The small blood specs in the Bronco either meant the evidence had been planted or that Simpson was one of the cleanest murderers in history (Lee and Labriola, 2001, pg 208). Of course, the reality was that many smaller specs could have resulted if Simpson had removed an outer layer of clothing he was wearing during the murder and placed in a container later disposed of. Simpson's shoe print in blood was found on the driver's side floor that contained his DNA and Brown's. This piece of evidence was mentioned only in passing and overshadowed by the three small specs of blood collected from outside the door at a later date, August 26th (Nickell and Fischer, 1998, pg 208).

The bloody socks were also questionable evidence (evidence 6). The dark pair of socks had been seen on the Simpson bedroom rug in camera still shots, but in video taped

evidence several hours later, were gone. The sock blood contained EDTA preservative and was supposedly dropped onto the socks when they were constricted and not while being worn (Lee, Labriola, 2001, pg 242). FBI DNA expert testified that a false positive for EDTA could come from laundry detergent used to clean the socks. Nevertheless, false positives sounded suspicious and the idea of planted evidence was seeded in the juror's minds (Nickell and Fischer, 1998, pg 214).

The evidence in the Simpson case sided with the prosecution, Assistant District Attorneys Marcia Clark and Christopher Darden. Prior to trial, the defense team dropped its motion to block DNA evidence, thereby legally accepting that the results of the Prosecution's tests were sufficient for use in trial (Nickell and Fischer, 1998, pg 210). As one of his first rulings, Trial Judge Lance Ito ruled that the prosecution had a right to test 90% of each blood sample, allocating only 10% available to defense for independent tests (Lee and Labriola, 2001, pg 224).

Some samples were so small they couldn't be reasonably split. Many of the smallest samples "had come back 'inconclusive' because of an insufficient quantity of DNA in the samples or because of deterioration." (Lee and Labriola, 2001 pg 229) Deterioration was a result of the DNA evidence being collected in extreme heat and high humidity causing some of the blood spots to remain wet overnight. Dr. Henry Lee, DNA expert for the defense, later noted in his book:

> "The way to collect a valid sample is to first moisten the bloodstain with a wet fabric swatch, thus absorbing the blood. Then an absolute necessity for preserving DNA is to dry the swatch as soon as possible in order to prevent bacteria and fungi from consuming human DNA. This had to been carried out at the time by the LAPD. Testimony would later show that the crime scene security and evidence gathering had not been done in accordance with established protocol. Instead, samples had been collected first at Rockingham and then at Bundy. The collectors then returned to Rockingham and stored their samples in plastic bags kept in their unrefridgerated van. It was not until 12 hours later that they arrived at the lab to begin drying out the samples." (Lee and Labriola, 2001, pg 229)

Dennis Fung, the criminalist, was indeed at fault for the collection mistakes at the scene and was blamed for many additional mistakes made by investigators. Dennis Fung's trainee assistant, Andrea Mazzola, had only been at one other crime scene (Lee, Labriola, 2001, 230). Fung himself handled evidence without gloves as was proven in a well publicized cross examination video picturing him without gloves at the crime scene. Fung had used a blanket from Brown's townhouse to cover her body and several other items from her house, introducing contamination unnecessarily.

There was some surprise that an untrained forensic criminalist such as Mazzola would be dispatched to a high profile crime scene. Mazzola was certified to watch and assist, but Fung had ordered her to collect the vast majority of blood samples, beyond what her training protocol had allowed for. Mazzola was accused of handling blood evidence improperly and receiving the vial of Simpson's blood sample and placing it in a trash bag and then placing it into the unrefridgerated van. This last point is important since Detective Vannattter, the detective who had Simpson's blood drawn, was only a few doors away from the sample's drop-off point in the police station. Rather than follow protocol, Vannatter carried the sample in his pocket for three hours and was seen at the crime scenes with the vial. (Lee and Labriola, 2001, pg 231, 241).

The Prosecution

The opening of the Simpson trial was decidedly in the hands of the Prosecution. The pre-trial hearing made public almost all of the evidence including the positive DNA match of blood at the crime scene to Simpson. In her opening, Clark's description of the prosecution's case boiled to two general premises. She would present evidence of

Simpson's earlier physical abuse of Brown and his outrage of being excluded from his daughter's dance recital that day. She also promised the jury that Simpson's "trail of blood extended from the Bundy crime scene to his bedroom at Rockingham." (Lee and Labriola, 2001, pg 227) Detectives Vannatter and Fuhrman had seen a trial of blood leading to Simpson's front door, but the blood was mentioned only in passing, a critical flaw since the blood trail could have connected the Bronco to the glove then to the front door to Simpson (Nickell and Fischer, 1998, pg 206). DNA was not specifically mentioned during the opening because "the evidence was considered so utterly convincing and overwhelming that it would have the greatest impact later in the trial." (Nickell and Fischer, 1998, pg 211)

The prosecution's long jumble of scientific evidence helped to nullify the jury (Fridell, 2001, pg 54). Jury nullification is the legal term used to describe a jury which is so confused or lost about scientific evidence that they discount the evidence entirely and base their verdict on the testimony of other witnesses and circumstantial evidence. Jurors effectively take the DNA evidence out of the case and ask themselves, "If we didn't have this DNA evidence, would we still convict the defendant?" Jury nullification was a serious problem during the early 1990's when DNA evidence was complex: DNA professionals hadn't taken the time yet to create a coherent description of DNA fingerprinting that a layman could understand in a relatively short time. The prosecution gave the jury a scientific lesson that went over their heads.

> "The Prosecutors struggled to make the mystifying material sound less like scientific gobbledygook and more like carefully examined evidence and meticulously assembled information that pointed a damning finger of guilt at the defendant. There were times, nevertheless, when jurors appeared to be too preoccupied with other matters or about to doze off while lawyers and witnesses droned on for weeks abut such mind-boggling matters as Hardy-Weinberg Equilibrium theory, population restructuring, PCR, RFLP and DQ-alpha." (Nickell and Fischer, 1998, pg 212)

On July 6, 1995, the Prosecution rested. The length of the prosecution's case actually turned the jury off to evidence and jurors couldn't pick out what evidence was important versus what wasn't important.

Jury nullification of the DNA evidence resulted in an empty case for the Prosecution. Simpson couldn't be accounted for during the time of the murders and his past history of spousal abuse was well known to the public, but to the sequestered jury, these two pieces of information were victim to the Prosecution's cutting room floor (Lee and Labriola, 2001, pg 188). Evidence of Brown's beatings and former 911 calls wasn't entered into the record during the trial, only during the pre-trial hearing.

The Defense

DNA evidence can be compelling when sufficiently described to juries. "But as *People v Casto* proved, the mere existence of DNA evidence does not always lead to a conviction. Equally important is the manner in which the DNA evidence was collected and tested. And that was where the Simpson defense team concentrated their attack." (Fridell, 2001, pg 49)

The defense team admitted that the odds of matching DNA to O.J. Simpson were in general correct and at some points even conceded that DNA evidence belonged to O.J. Simpson. Questions about crime scene security, search and seizure issues, handling and collection of DNA samples and the later appearance of blood stains on the socks and gate all seemed speculative and the Simpson defense team capitalized on public skepticism towards the LAPD and their past treatment of minorities.

The defense led a two-pronged attack. The Dream Team would cry conspiracy when the victim's blood was found at Simpson's estate and contamination when Simpson's blood was found at the crime scene.

DNA on the gate of Brown's townhouse and the bloody socks was found several weeks after the initial police search and was supposedly planted to solidify the prosecution's case. The socks and gate contained EDTA a preservative found in blood vials to prevent coagulation was identified during DNA testing. In addition, the DNA concentrated in the gate and sock samples seemed unusually high. These samples had been found after the initial scene search, and supposedly open to the elements and contamination, then they should have exhibited DNA deterioration. This was not the case. The defense pointed the finger at police investigators for planting the evidence with the missing blood from Simpson's sample vial. (Lee and Labriola, 2001, pg 230)

The vial of blood collected from Simpson the day after the murders was placed in the custody of Detective Vannatter. "Later records revealed that a significant portion of this blood was missing. The police could not account for it." (Fridell, 2001, pg 50) The missing blood leads to speculation that the vial had been used to place Simpson DNA on the Brown townhouse gate and the bloody socks (Fridell, 2001, pg 50).

To defend the five droplets of Simpson's blood heading away from the crime scene the defense claimed the swatches for the bloodstains had been switched. First the team claimed that the 5 swatches for the 5 droplets were switched with swatches from Simpson's vial. Inconsistencies with the DNA fingerprinting method cause the defense team to change plans. Now the contamination had happened in the lab. First blood droplets leading away from the scene containing the true murderer's DNA had "degraded

so severely that DNA disappeared entirely in each of the five separate blood drops. Next a transfer would have had to take place in which the DNA present in Simpson's blood sample made its way into each of the blood drops themselves without any detection of EDTA (as in the socks and gate). Traditional blood tests not susceptible to contamination typed to Simpson reflecting a 1 in 200 match." (Nickell and Fischer, 1998, pg 212)

Next, the defense team called Dr. John Gerdes, director of a DNA lab in Colorado. Although he hadn't personally seen the LAPD crime lab, he testified, "The lab had a serious problem with contamination of evidence." (Fridell, 2001, pg 52) Dr. John Gerdes's testimony amounted to nothing more than junk science, or scientific knowledge misapplied, applied to inappropriate situations or statistics and research taken out of context. When he testified that LAPD crime labs most likely cross-contaminated specimens in the lab, without having personally investigated it himself, he should have been disqualified as an expert on the topic (Fridell, 2001, pg 56). Instead, Gerdes made it "sound as though Simpson's DNA fingerprints had shown up by accident in someone else's blood. Gerdes' initial testimony sounded reliable enough to someone unschooled in science. The judge in the Simpson case did not question it" (Fridell, 2001, pg 56). Gerdes's clear and concise, yet inaccurate, testimony hit home with the jury. His testimony was just enough scientific evidence to counter the Prosecution's DNA experts and to under cut their mathematically confusing testimony. The defense team made their presentation concise and coherent – two qualities that the Prosecution's team had failed to get from their experts.

Other than questioning the supposed racially induced actions of Mark Fuhrman, "Simpson's lawyers offered the jury no clear reason why the LAPD would want to frame

their client, much less any proof" (Fridell, 2001, pg 51). By tearing the confidence of the DNA collection out from under the Prosecution, the defense raised the necessary doubt in the juror's minds to bring a not-guilty verdict.

The Verdict

"After listening to 9 month's worth of testimony, the jury deliberated for less than 5 hours before reaching their verdict at 10 AM on October 3, 1995. Two members of the jury of the 12 – person jury voted guilty at first. But after further discussion, they changed their vote, and the jury was united in a verdict of not guilty." (Fridell, 2001, pg 52) The two jurors who initially voted guilty still believed he most likely did cause the death of Brown and Goldman, but couldn't shake questions about DNA evidence and collection techniques.

Ultimately, the verdict destroyed the public's opinion of the infallibility of DNA evidence. Dr. Henry Lee simply states, "We should do a better job in conducting criminal cases and forensic investigations." (Lee and Labriola, 2001, ph 248) Numbers and long odds matching a suspect to the crime scene won't convict if the evidence was mishandled. Forensic experts were now accountable for the actions while at the scene and held to a higher standard when locking up evidence. Lastly, Simpson's case was the last in a long line of racial based cases in LA, sending a strong signal to LAPD and city officials that citizens were not going to accept questionable police practices in their neighborhoods.

Abuelas de la Plaza de Mayo

Argentina was mired in seven years of civil war and military dictatorships from 1976-1983 (Lampton, 1991, pg 87). World War II German and Italian war criminals and their sons led the fascist regimes. In an effort to terrorize political dissidents, they kidnapped upwards of 12,000 people including pregnant women and women with young children (Lampton, 1991, pg 87). Mothers were brutally killed. These women left behind their children – some young babies under the age of two, others born in prison cells only to be taken away. These children were then handed over to childless couples of the military and police state regimes, or sold to a black market in Europe.

In 1977, several political groups opposed the actions of the regime. One of the most famous was the Abuelas de la Plaza de Mayo, or the Grandmothers of the Plaza of May. These women were searching for evidence of their kidnapped daughters. Grandmothers wished to be reunited with their grandchildren. In 1983, the Plaza de Mayo was supported by Argentina's new leader, Raul Alfonsin (Lampton, 1991, pg 87).

In tracking down children, the grandmothers relied heavily on anonymous tips and nameless callers. Torture center janitors had information regarding whether certain women had been allowed to give birth. Elementary school teachers would see birth certificates, many of which were obvious forgeries. Children would also appear in families where it was well known that the mother had never been pregnant. Information was gathered from some political prisoners released during the World Cup games when foreign athletes refused to play games in Argentina (Bass, 1993, page 68).

By 1983, the Plaza de Mayo had over 144 leads. Unfortunately, there was difficulty in identifying bloodlines and verifying children's true identities. The

Grandmothers used blood typing but this method was better at eliminating parents rather than uniting a child with the correct set of grandparents. Without positive identification of the child's true family, grandmothers would be unable to claim their grandchildren.

At this point, two representatives of the Plaza de Mayo visited the American Association for the Advancement of Science (AAAS). The representatives asked for scientific expertise and pleaded for a method that would link missing children with their true families. The AAAS pointed to Luca Cavalli, a geneticist-mathematician at Stanford. Cavalli determined that HLA, or human leukocyte antigens, would be the best method available for determining family lines. He sent Mary-Claire King to head the expedition. She spent time in Buenos Aires constructing a reliable testing program which would not only help identify children in false families, but also act as national voluntary database to link these children with their blood relatives (Bass, 1993, pg 68).

The HLA method proved relatively reliable but was quickly replaced with mitochondrial DNA. King and Cavalli determined the method would create false positives in 1 in 500 tests (Lampton, 1991, pg 88). Several children were false positives.

HLA typing only works when multiple grandparents are available for testing, as in the case of the first identified child, Paula Eva Logares. With three living grandparents, King and her colleagues were able to determine Logares was not the daughter of an Argentinean police chief but rather had been kidnapped at the age of two. The HLA typing which assisted her grandparents is not available when many members of a family are killed, including aunts, uncles and grandparents. Mitochondrial DNA can be more efficiently used to determine whether a child was a great-granddaughter or related to a maternal family member. King and Cristian Orrego of the AAAS created a program

in Argentina for mitochondrial DNA testing to carry on the mission (Lampton, 1991, pg 89).

King left the program in the hands of several trained experts in Buenos Aires who, at the time of first meeting them, "were just kids in college" (Bass, 1993, pg 68). At the time of her Omni interview in 1993, 50 cases had been solved, 12 more children had been located and yet to be identified and 150 children were still not found.

World Trade Center Bombing, Bosnia, and Osama bin Laden

The most recent large-scale application of DNA fingerprinting technology is the identification of remains of victims of the World Trade Center Bombing from September11, 2001. The identification process is using the state of the art techniques in an attempt to bring closure to families of the victims.

The task of identification has fallen to the New York City Medical Examiner's office. The daunting task is best recognized by the fact that of "more than 2,800 people killed in lower Manhattan on 9-11, fewer than a 1000 have been identified. Over 19,000 human remains are being tested for DNA." (Scelfo, 2002, pg 14.) One employee, Ellen Borakove told Newsweek magazine "As many as 100 remains have been linked to one person." (Scelfo, 2002, pg 14). DNA analysis could take another year to complete.

The use of DNA to identify victims of terrorism is not new. DNA has been used to identify many of the victims of the Bosnia-Herzegovina civil war and ethnic genocides. Bones and other human remains have been located throughout the country in mass graves. Much like the Dirty War in Argentina, these victims were often kidnapped and killed with little or no identifying paperwork or witness evidence. This means that

families with missing loved ones have no idea where their relatives could be. The ICMP or the International Council on Missing Persons operates the testing center through existing scientific labs in Croatia. "New developments in DNA identification analysis, such as low copy number DNA profiling and new human DNA qualification systems will significantly aid the mass identification of human remains." (Maruscaron, 2001, pg 1244)

The biggest challenge in the Bosnia case is the quality of DNA samples. These mass graves, still being located and exhumed, are 5 to 10 years old. The bodies are badly decomposed and not preserved well. "However, genomic DNA has successfully been used to identify more than 80% of missing persons in Croatia. In the first half of [2001], the laboratory prepared 158 genotypes from excavated human remains and successfully matched 80 of them with the DNA from 1182 samples from relatives of missing persons." Laboratory leader, Milovan Kubat points out "DNA identification is very slow, technically demanding and expensive, but it is very important for the resolution of war traumas and the grieving process." (Maruscaron, 2001, page 1244)

The FBI Crime Lab is waiting to test a DNA sample related to the World Trade Center Bombings. The Crime Lab has been named the official site for testing DNA samples from Osama bin Laden. President Bush has ordered the capture of the Al-Qaeeda leader dead or alive. In order to identify bin Laden, the FBI is "standing ready" and will expedite DNA testing for the Defense Department (Barovick, 2001, page 17).

One complication is how to compare the DNA sample. Since the U.S. has no known sample of bin Laden's DNA, the FBI lab plans on using Mitochondrial DNA analysis to link bin Laden with his mother. She, as well as many bin Laden family

members, live in Saudi Arabia. Though Osama bin Laden has a plethora of siblings, "bin Laden is thought to be the only child of his mother." (Barovick, 2001, page 17).

The catch is whether FBI agents will be able to get a tissue sample from bin Laden's mother. The Saudi regime has been silent and may prove unwilling to allow such testing (Barovick, 2001, page 17). In this case, the testing method used in identifying Thomas Jefferson's descendants, to be discussed, may prove a good alternative. In this method, bin Laden's Y-chromosome would be compared with those of his brothers, several of who live in the United States.

Nature Conservation

Nature Conservationists are using DNA to help solve some of the most serious crimes towards Endangered Species: poaching. They are doing this through DNA databases and maps of animal populations by location.

Tagging and capturing animals used to be the best method of estimating animal populations by location. The tagging method doesn't help when animals are hunted and poached. These animals die unnaturally early and hunters destroy their tags. These animals are never recaptured, thereby inflating or deflating population estimates.

One solution has been the use of DNA typing of concentrated animal populations. Groups of animals are analyzed according to location. The method assumes that animals breed within a relatively small group of peers all located in the same region. Diversity within the species is more likely tied in with location rather than by randomness.

The National Fish and Wildlife Forensic Laboratory in Ashland, Oregon is the only animal-only DNA and forensic science testing lab in the world (Buckles, 2000, pg

15; Lampton, 1991, pg 90). The lab specializes in researching poaching and over hunting as well as the migratory and mating habits of animal species in the United States. The lab collects specimens and catalogs DNA by location and approximate age. Mating habits can be examined through ancestral research.

DNA typing programs include those lead by Stephen Fain of the U.S. Wildlife Services and John C. Patton. Fain studied American bear DNA in the early 1990's and later studied American elk species. Patton created a database at the University of Washington in Missouri for African and Asian elephant species. He can identify the nation elephant tusks and ivory originated from by examining meat still attached to the tusk ends (Lampton, 1991, pg 91).

One such example of success means that Lowland Gorillas may be able to mate more frequently and with more genetic diversity. Gorillas in the Kehuzi-Beiga National Park in the Republic of Congo were tested for genetic diversity. The park sent samples to the U.S. lab for testing. The results show that gorillas were mating according to their north-south location. A small narrow strip of land in the center of the park condensed due to housing developments, prevented gorillas from crossing over to the other half of the reserve. Plans are underway to widen the narrow strip of land (Buckles, 2000, pg 15)

A model program has been the Grizzly bear database from the Western United States. Grizzly bears located in Glacier National Park have been entered into a database in the past several years. It is hoped that the program will help raise the Grizzly bear population, which according to estimates is less than 800 south of the Canadian border (Fridell, 2001, pg 78) Nature volunteers gather hair and tissue samples from tree rubbing

and analyze the data (Belcher, 2001, pg 32). Grizzly poaches are often after the paws and gall bladders of bears; the organs have Chinese medicinal value on the black market.

Katherine Kendall, a research ecologist working on the Grizzly project, has pointed to the positive results. "Using live capture, we're lucky to capture 25 bears in a year" (Buckles, 2000, pg 15). Collecting samples of 212 distinct bears meant the previous estimate of the bear population in the Glacier Park was 150 specimens too small – they currently suspect closer to 350 bears live in the refuge (Buckles, 2000, pg 15).

A new program in India is being created based upon the Grizzly project. In 28 national wildlife preserves, Indian Tigers are being poached. Smuggling rings have been successful in avoiding prosecution because no method had been determined to track where the tiger was killed. The programs, still under Indian government, would DNA fingerprint tigers by location and then give authorities the evidence they need to test the location where the tiger was captured. (Belcher, 2001, pg 33)

The Grizzly project has already worked for a different species – whales. With strict international guidelines on protecting endangered humpback, blue and Bryde's whales, the Earthtrust environment group is testing whale meat found as a delicacy in Japanese restaurants. The meat is ordered and then smuggled out of the restaurant. The DNA is copied with a portable PCR copying machine called a minicycler. This way, illegal whale meat isn't transported outside the country but the PCR copies are. A database of whale DNA based on species and location has already been created and restaurants selling illegal whale meat have already bee identified (Fridell, 2001, pg 75).

Poaching also includes plant species. Tree rustlers who illegally chop down trees in protected areas are as difficult to catch as whale hunters. Canadian officials collect

DNA from the stump of an old growth tree and compare that DNA to the logs found in suspicious trucks. The DNA matches mean convictions and fines (Fridell, 2001, pg 77).

Romanov Family

In 1917, the Russian imperial empire fell during Lenin's Bolshevik revolution. The royal family, hiding in Ekaterinburg, Siberia, thought their military servants were guiding them to safety. Instead, the military personnel followed orders to murder the family and dispose of the bodies. Czar Nicholas II Romanov, Czarina Alexandra Feodorovna, daughters Olga, Tatiana Maria and Anastasia, son Alexis Nicolaievich, Alexis's personal physician Sergei Botkin, a maid, cook and footman were targeted.

In the basement an execution squad greeted the family. Commander Jacob Yurovsky ordered his men to fire. The family was struck dead with the first shots except Alexis and Anastasia who were then beaten to death. Jewels sewn into the family's coats were recovered as proof of the murder (Nickell and Fischer, 1998, pg 284).

Czar Nicholas II, the czarina, their children, and servants were first buried in a mineshaft. Their clothes were burned to make identification more difficult. Local rumors about the mineshaft caused the assassins to recover the bodies. The corpse's faces were sprayed with hydrochloric acid and two bodies burned, later identified as Alexis and Anastasia. Having used all of their fuel on the two bodies, the Commander set out to find a burial spot for the remaining bodies before locals would discover their activities. Because of the swiftness of burial, little was known about the details of the event – what was known was the Czar and his family disappeared. Months later, Russian White Armies (anti-communist) conquered the town and locals led them to the mine

shaft. Belt buckles, buttons and the physician's dental plate let officials know that indeed the family was dead (Nickell and Fischer, 1998, pg 284).

In 1920, a young woman rescued from a river near Berlin, Germany claimed to officials that her true name was Anastasia Romanov. Her resemblance to the princess was so striking that newspapers and news accounts stated that her story was very possible. Some distant family members believed her. Anastasia's former tutor and godmother disagreed while a personal servant of Anastasia's believed. A private investigator in 1927 concluded she was a Polish peasant woman who had disappeared three days before and had attempted suicide. Nickell and Fischer state she died in 1984.

In 1979, filmmaker Gely Ryabov discovered the mass grave but kept it a secret in fear of communist retaliation. In the 1980's, Soviet Union President Mikhail Gorbachev declassified thousands of government documents. The dying declarations of several of the military commanders at the Czar's grave site along with those of Commander Yurovsky were discovered. Ryabov felt secure during the "openness period" to publicly announce the gravesite (Nickell and Fischer, 1998, pg 285).

The mass grave was unearthed in Siberia. Nine bodies were found instead of the eleven killed in the basement. It wasn't known right away that two other bodies had been burned outside the mineshaft. Bone samples were sent to the Armed Forces DNA Identification Laboratory in Maryland. The lab compared mitochondrial DNA from the bone samples to samples provided by Prince Phillip, husband of Queen Elizabeth II (related to the Romanov's on his mother's side). After comparing the samples, the lab declared that the grave did belong to the Romanov family, their cook, footman, maid and their physician (Fridell, 2001, pg 84).

In 1992, officials began to wonder whether Anna Anderson was indeed Anastasia. A blood sample taken during one of Anna's last operations, was compared to the mitochondrial DNA from Prince Phillip (Nickell and Fischer, 1998, pg 288). "AFDIL tests showed that the mtDNA samples did not match. Anna Anderson was not Anastasia Romanov." (Fridell, 2001, pg 85) Taking the DNA testing a step further, they tested the DNA from a maternal grand nephew to see if Anna was Franzisca Schanzkowska, a polish factory worker, as was suspected in 1927. The test came back positive (Nickell and Fischer, 1998, pg 288).

Thomas Jefferson and Sally Hemings

The major question for hundreds of descendants of Thomas Jefferson was whether the Third President and American Founding Father had fathered several children with one of his slaves, Sally Hemings. Positive identification of Jefferson as the father would not only change the facts of history as they are known, but would alter the image of Jefferson as the reluctant slave owner. (Golden, 1998, pg 26).

Sally Hemings was mulatto, half white – half black. She was the daughter of Jefferson's father-in-law, John Wayles, and his slave, Elizabeth Hemings. In 1802, rumors spread that "the president of the United States from 1801 to 1809 was having an illicit love affair with Sally Hemings, a woman 28 years younger than himself." (Fridell, 2001, pg 87) Jefferson's strong sense of personal privacy meant that he would never speak publicly about the accusations.

To solve the mystery, several descendants of Sally Hemings hired the retired pathologist Eugene Foster. Foster collected blood from 14 Jefferson and Hemings

descendants. He examined the Y-chromosome of the descendants – the "distinctive, largely unchanging chromosome" is passed from father to son (Golden, 1998, pg 26).

After examining the results, Foster determined that descendants of Eston, Heming's last son born at Monticello in 1808, were indeed descendants of Thomas Jefferson. Their Y-chromosomes were consistent and closely related to known white descendants of Jefferson. Results for descendants of Heming's first son were negative for Jefferson and his two nephews (Golden, 1998, pg 26). The results were published in the British journal, Nature, and several new tests in 2000 seemed to support Foster's conclusion (Fridell, 2001, pg 89).

The continuing contention of the Monticello society, made of descendants of Thomas Jefferson, is that the testing was inconclusive. Some reports show that the testing may need to be redone. "In 1998, Y chromosomes from descendants of one of Heming's sons were matched to a descendant of Jefferson's paternal uncle." (Schute, 2000, pg 79) Because some of the DNA used in the testing was that of Jefferson's uncle (father to the two nephews also tested as possible fathers), Monticello Association members claim that it is more likely that Hemings had one child or more fathered by Thomas Jefferson's nephews and not the past President himself.

The DNA link was inconclusive enough that on May 5, 2002, the all-white Monticello Association voted almost unanimously to deny the Hemings descendants membership (Hewitt, 2002, page 123). "John Works Jr. who led the opposition against the Hemings application points out that the DNA evidence proved only that Sally's descendants were related to a male Jefferson. A more likely candidate for Sally's lover is

Thomas's brother Randolph, who frequently visited Monticello and its slave quarters." (Hewitt, 2002, page 124)

Jesse James

Jesse James's death is one of the many historical mysteries of American legend. Jesse James, one of the most infamous outlaws of the West, was shot to death for ransom money in Kearney, Missouri in 1882. His body was buried first at a family estate and then later moved to the Mount Olivet Cemetery. Because of Jesse James long history of outrunning the law, in combination with several suspicious look-alikes, rumors had spread through the Mid-West and the South that Jesse James had faked his death and had lived the remainder of his life in hiding.

To examine this theory, The George Washington University law and forensic science professor, James E. Starrs, had the body exhumed in 1995. DNA from the remains were tested against 6 known grandchildren of the outlaw. "Mitochondrial DNA analysis of bone fragments and hair samples extracted from the remains of Jesse James have confirmed beyond a shadow of a doubt … had indeed been the man." (American History, 1996, pg 8).

This may not be the end of the story, however. Schute, a writer for U.S. News and World Reports, writes "Mitochondrial DNA gathered from teeth at a Missouri grave matched descendants of James's sister. Proponents of J. Frank Dalton, a Gran-bury, Texas, man, say he's the real outlaw. They are calling for more DNA testing." (Schute, 2000, pg 79) Future tests on the remains of J. Frank Dalton were desired, but the results haven't been reported. It is unlikely, however, that the DNA testing would change the

results since mitochondrial DNA is passed from mother to child, so Jesse James's DNA should be extremely close in nature to that of his sister (Schute, 2000, pg 78).

Tomb of the Unknown Soldier

On Memorial Day in 1984, Ronald Reagan led a special ceremony at Arlington National Cemetery for veterans who had died while in the line of duty. In the ceremony, the remains of a U.S. soldier were laid to rest in the Tomb of the Unknown Soliders. There were no means at the time to identify the man, and his I.D. that had been discovered with the body, had been lost. His burial was to honor him and other fallen soldiers of the Vietnam War.

Unfortunately, the Tomb of the Unknown Soldier may have been inappropriately named. At the time of the body's discovery, recovery team personnel recall that the I.D. card name was similar in nature to that of a young fighter pilot who had been shot down in the same area of An Loc on May 11, 1972 (Fridell, 2001, pg 82). First Lieutenant Michael Blassie had flown over 130 missions in Vietnam. His family grieved the loss of their son and closure was difficult without a body.

An Army review board charged with identifying and returning bodies from Vietnam closed the case on the Unknown Soldier in 1980, when it was deemed impossible to determine the true identity. The family of Blassie heard through other officers about the body's possible I.D. Unfortunately, the file on the Unknown Soldier was destroyed when the body was placed in the tomb.

In 1995, the Defense department suggested a new policy of DNA testing for MIA soldiers (Fridell, 2001, pg 83). In 1998, the family requested that the body be exhumed

and DNA tested. The Defense Department was hesitant to do such since the opening of the Tomb may change the symbol for America's veterans. Many veterans groups disagreed. "Veterans groups argue that there is a moral imperative to do everything possible to account for missing service members" (Kulman, 1998, pg 5).

Finally, in 1998, the tomb was opened and the remains tested. The Armed Forces DNA Identification laboratory that had tested the DNA remains of the Romanov family took DNA from the remains (Fridell, 2001, pg83). The mitochondrial DNA matched that of his mother and was turned over to the Blassie family for proper burial. "As a result, the Defense department declared that never again would the remains of a soldier be buried in the Tomb of the Unknowns. Thanks to DNA fingerprinting, it is highly unlikely that there will ever be another 'unknown soldier'" (Fridell, 2001, pg 83).

Albert DeSalvo

A criminal much closer to home in both time and location, Albert DeSalvo's name still upsets several Boston area families. In January 1967, he was identified as the infamous Boston Strangler, a serial killer who preyed upon single women, first raping his victims then strangling them with stockings.

The case had gone unsolved for years and frustrated police and detectives. The 33-year-old construction worker had been arrested on rape charges unrelated to the Boston Strangler case. He confessed to the Strangler case even though his own rape case was dissimilar to that of the Boston Strangler.

The questions surrounding DeSalvo's guilt have plagued the DeSalvo family and the family of his last victim, Mary Sullivan. "Casey Sherman, a TV producer, had

become convinced that Albert wasn't the Strangler – and wanted to use DNA evidence to prove it." (Rosenberg and Kirch, 2001, pg51) He is supported by details of the investigation and questions that have been around since Albert DeSalvo's confession. "Investigators suspected that the strangling that plagued Boston from 1962 to1964 were copycat crimes and not the work of one serial killer. No physical evidence ever linked DeSalvo to the strangling. Prosecutors didn't even have enough proof to charge him; he was convicted and sentenced to life in prison for the unrelated rapes." To further the case on behalf of DeSalvo, his confession was inaccurate and inconsistent with the evidence collected by the Medical examiners office but consistent with some of the evidence collected by the police. Only the true killer would be able to confess to the nature of the crime as was determined by the ME's office. (Rosenberg, 2001, 52)

Casey Sherman has hired pro bono forensic scientists, including Henry Lee (O.J. Simpson) and James Starrs (Jesse James). Her body was exhumed in 2001. Whether DNA testing can be done on the final victim, Mary Sullivan, hasn't been determined and so far the evidence hasn't been conclusive enough to report.

DNA evidence from Mary Sullivan may not be adequate for fingerprinting, but the State of Massachusetts has evidence that will work. State Attorney General, Tom Reilly was hesitant to release case information about the Strangler and at first refused to reopen the case. "But a round of publicity sent officials digging through their archives, and last fall the state announced that it had unearthed DNA evidence of its own: semen from the crime scene." Casey Sherman and Richard DeSalvo (Albert's brother) sued Massachusetts to test the DNA, but the state has only provided a small sample. A judge

placed a gag order on the case, and nothing further has been reported on the semen sample. (Rosenberg, 2001, 52)

Unfortunately, the potential use of DNA evidence has come too late to exonerate Albert DeSalvo. Fellow prison inmates murdered him in 1973. To some extent, this is the reason why many family members of DeSalvo and his victims don't want to dredge up the past. How would they handle the news that DeSalvo wasn't the killer? His family would now have to live with the idea that their relative had been forced into confessing for crimes he didn't commit and the possibility that his prison murder was linked to his Strangler confession. The victim's families would have to live with the truth that their relative's murderer had been allowed to go free and unpunished for the crime. The victim's sister Kathleen Johnson states, "I feel it can only cause more hurt. I wish they'd leave it alone" (Rosenberg, 2001, 51).

Conclusion

Whether it's a murder mystery, identifying family, living and deceased, or investigating great historical icons, DNA fingerprinting is solving the many cases that plague society. Future testing can prevent unknown bodies from being listed as John Doe forever. The applications for paternal and maternal suits, rape cases, and missing person have already been proven. What remains to be seen is how fair into the past DNA fingerprinting can dig.

CHAPTER 5: DNA DATABASES

Introduction

DNA Databases are both the power driving DNA forensics and a phenomenal crime-fighting tool for solving cases. A DNA database samples the larger population from which the statistics regarding population genetics are derived. These statistics are what lend a given level of discrimination to a DNA profile used in a court of law. At the same time, the forensic indexes within a DNA database are used to solve crimes.

However, a system as powerful as this raises serious ethical concerns. Civil libertarians ask: Who will be included in the database? What personal information is revealed by DNA samples? Who will have access to the information? Despite these concerns, the benefit of this technology easily outweighs the possible problems.

The population of the United States has come to accept criminal fingerprinting and the Automated Fingerprint Identification System (IAFIS), a national fingerprint database maintained by the FBI. DNA profiling technology and its associated national database should be treated in the same fashion.

CODIS

In the United States, the mandate for a national DNA database was given in the DNA Identification Act of 1994. By 1998 the Federal Bureau of Investigation publicly unveiled the National DNA Index System (NDIS). The Combined DNA Index System (CODIS) is the software created by the FBI for use with the database program. The entire program is often referred by this name, and will be referred as such throughout this

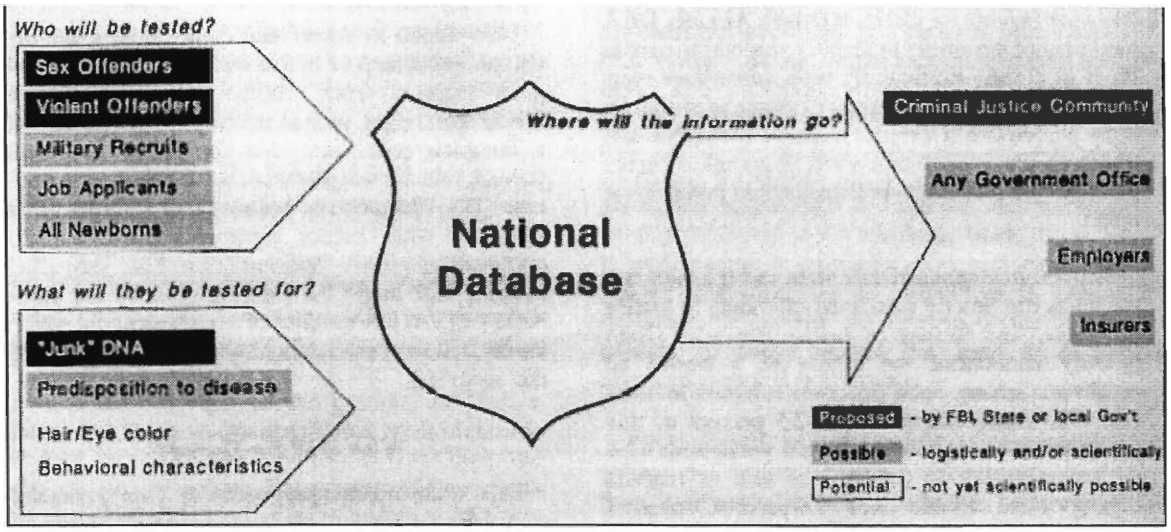

Figure 15 - CODIS Diagram

(Office of Technology Assessment, 1998)

paper. CODIS is a nation wide repository consisting of an offender index and a forensic index. CODIS consists of two indices: an offender index and a forensic index. The offender index lists submitted felons, while the forensic index has samples from the scenes of crimes. (Federal Bureau of Investigation, 2000)

Although this system is Federally created and organized, it is really a structure for the forensic law enforcement communities of each state to share information. Currently, 49 states are involved, via 153 participating laboratories. The CODIS database contains over 900,000 offender and 33,000 crime profiles. The CODIS software is provided to each of these labs that allows samples to be run against the database and submissions to be sent in to the database as well. (Adams, 2002)

A standardized DNA profile was accepted for usage with the CODIS system, allowing comparisons of samples to the database and from entry to entry within the system. The PCR profiling method was chosen with thirteen STR loci. The large number of loci used account for the lower discrimination per locus found in PCR testing by a significant margin and exceeds other systems around the world. The particular thirteen loci used in the CODIS standard are show in figure 16, below. (Butler, 2002)

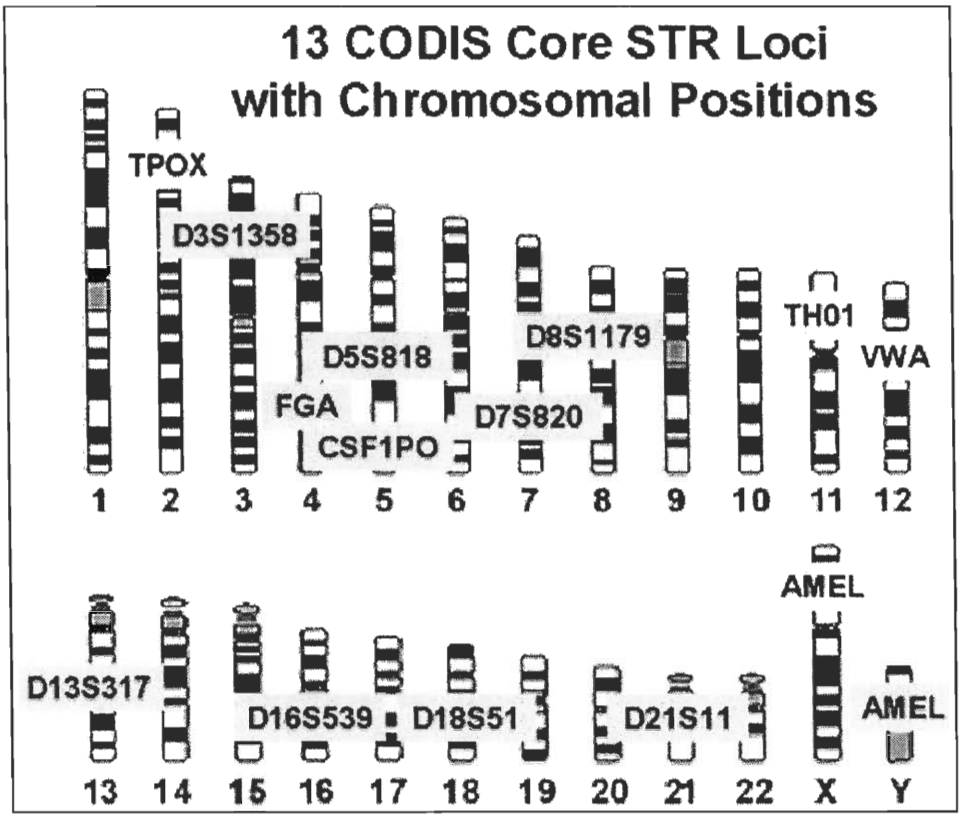

Figure 16 – STR Loci Used For CODIS PCR Profiling

(Butler, 2002)

Entries in the database are composed of the following pieces of information:

- Sample Identification Number
- Agency Identification
- Associated DNA analysis technician
- DNA Profile (as detailed above, see figure 16).

This data entry design is one of the strongest features of the database. The information regarding the identity of the sample (Felon's name, case or crime scene) is kept behind the blind of the files at the parent agency. It is only after a sample matches one of the many anonymous (identified only by a sample identification number) entries in the database that anything else may be revealed. (Adams, 2002)

Whenever a member of the CODIS system has an unsolved case with a DNA sample, it may be profiled and run against the system. If a match is found, the information is sent to the particular technician at their agency for follow up. Upon confirmation, the evidence regarding the identity of a suspect or a link to another crime is forwarded to the law enforcement team for use in their investigation.

Ethical Concerns

Many citizens and privacy activists have raised concerns regarding the new technology of DNA databases. However, the CODIS system within the United States has been well designed to cover these issues. In examining the ethical questions and implications of the CODIS database the features of the CODIS program and its analogue in the IAFIS program will be compared.

The primary concern voiced was the danger of a DNA sample being used to extract genetic information about the people within these databases by the government, corporations, or others. This question often misunderstands the nature of the CODIS database in storing DNA *profiles*, not DNA samples or DNA sequences. In the same way that the computerized fingerprint systems sample special locations on the fingerprint for comparison, so does CODIS sample the human genome. (Criminal Justice Information Services Division, 2002) The thirteen loci chosen *do not* map to any known genetic or health characteristics. These loci were explicitly chosen to provide identification but no other information. In addition to the nature of DNA profiles, the indexing system within the database disallows users the ability to look up a DNA profile for a particular person. Only database queries going in the opposite direction are allowed. Therefore, the

extraction of private personal information from DNA submitted for profiling in the database is not a realistic concern.

One valid issue raised was the status of DNA samples after being profiled and read into the database. Currently, these DNA samples are kept at the many forensic laboratories across the country in storage. It would make sense to initiate a program where samples were destroyed after being used or after a certain amount of time. The physical samples may also be kept in the case of recreating the original DNA profile. (Suarez, 1999)

The most important ethical issue however, is the question of who must submit samples to the database. There is a significant amount of variation on this issue, since the inclusion policy is decided by state. Most states include all individuals convicted of violent crimes and sexual offenses. Some states have a policy of including *all* convicted felons. Other states have begun including all individuals who have been arrested for violent crimes or sexual offenses.

It is clear that persons *convicted* of these felonies should be included in the database, but the line is much more blurry for arrests. To refer to our fingerprinting analogy, anyone arrested for a crime is fingerprinted. Therefore, it is no more of an invasion to take a DNA sample for profiling in the nation database than a fingerprint.

Conclusion

DNA used explicitly for profiling and national databases is completely analogous to fingerprints taken and stored nationally. The key difference between the usage of DNA for eugenics or intrusive prying into the characteristics of individuals is in the

regions of DNA examined. The public's primary concern of the extraction of genetic predisposition to disease is completely unwarranted since only allele profile information is stored, not DNA sequences. As long as DNA profiles choose loci that do not code for particular medical, physical, or behavioral traits DNA profiles will be the same as fingerprints and should be treated as such.

Two developments could threaten this status: advances in scientific knowledge that attribute specific traits to the profiling loci or the usage of collected DNA samples improperly. The first issue can be countered by updating loci used as discoveries are made. The second issue is more difficult, but could be dealt with by creating more responsible policies governing the use and lifespan of the DNA samples submitted to create DNA profiles.

Beyond these concerns DNA databases are having a dramatic impact on the nation. As of 1999, the CODIS system had helped solve more than 1,100 cases. (Federal Bureau of Investigation, 2000) It is clear that the advantages of our national DNA database and the related technologies far outweigh the potential risks and fears of the future.

CHAPTER SIX - CONCLUSION

DNA fingerprinting has arguably been called the greatest forensic tool in the history of science. As pressure increases from the public to prosecute the guilty, and acquit the innocent, society must weigh the importance of convictions against personal security and privacy.

For a DNA profile to serve as evidence in a court of law, all crime scene evidence must be processed and documented carefully. When evidence is collected correctly, it may then serve as the genetic seed for a DNA profile. A matching DNA profile, performed with a combination of 7-11 carefully selected probes, becomes powerful and persuasive legal evidence when verified through statistics and population genetics. DNA evidence has assisted in solving numerous previously unsolved mysteries, especially murders and rapes.

People v Castro and *People v O.J. Simpson* have proven the need to keep accurate and secure records when DNA is taken from a crime scene. The custody of the DNA should always be documented to ensure the validity of the sample. Custody of DNA samples in murder cases or involving celebrities should especially be handled carefully, and handed off to department experts rather than recent hirees. All police departments and criminal investigation teams need to store the evidence properly to prevent the deterioration of DNA and blood samples, and should use proper DNA collection equipment and refrigeration. DNA testing results will be considered legally invalid if proper lab techniques are not used.

To improve our knowledge of the probability of a DNA match, scientists must obtain more information on specific allele frequencies within certain human populations. This database issue is an important one. As scientists collect more samples from the population they are better able to determine the true mathematical probabilities of matches for criminal convictions. Without these mathematical odds, DNA fingerprinting will not prove as helpful as traditional fingerprinting in identifying unique individuals.

But with this database comes several moral quagmires. The fear that DNA fingerprint information will be used to deny health insurance or job applications is strong, with the public not realizing that exact sequence information does not reside in the database. Instead databases store information on the presence or absence of specific alleles. Thus databases store genetic haplotypes, not DNA sequences from which medical predispositions could potentially be established. FBI and other government agencies have not proven to the American public that their information systems are secure enough to develop a trusted method of collecting this population information without linking it to specific individuals who provided the DNA. However, once our research into the operation of the CODIS database was completed, it is clear that privacy was a key issue in its construction. The indexing system within the CODIS database does not allow users the ability to look up a DNA profile for a particular person. Even if a name was matched with a DNA profile, the thirteen DNA loci chosen do not map to any known protein encoding or health characteristics. These loci were carefully chosen to provide genetic uniqueness, but not other information. In this manner, information about medical predisposition and racial concerns are not kept in the FBI's database. The DNA

used explicitly for profiling and national databases is completely analogous to fingerprints taken and stored nationally.

New technologies for double matching DNA samples, and hiding the true identify of DNA donors, may help alleviate the public's fear. This data entry design is one of the strongest features of the database. The information regarding the identity of the sample (Felon's name, case or crime scene) is kept behind the blind of the files at the parent agency. It is clear to this IQP team that the advantages of our national DNA database and the related technologies far outweigh the potential risks and fears of the future.

The impact of DNA technology on the criminal justice system has been largely positive. Guilty individuals are more easily located and convicted, while the innocent are ruled out as suspects or even released from prison after false-incarcerations. As long as forensic experts and police can allow DNA fingerprinting to do its job without tampering with evidence, or botching the storage of samples, the criminal court system should continue to convict the guilty and allow the innocent to walk free.

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