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DNA Fingerprinting

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DNA FINGERPRINTING

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ABSTRACT

The purpose of this IQP was to trace the development and progress of DNA fingerprinting technology as it continues to be a integral part of judicial systems and societies world-wide. Much of the initial DNA fingerprinting methods and techniques have undergone substantial improvements to satiate the bombardment of skeptics, giving the technology more credibility in courts. However, there is still the unresolved issue of privacy laws that continue to complicate the issue of who should submit samples to DNA databases.

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EXECUTIVE SUMMARY

The purpose of this IQP was to investigate the controversial topic of DNA fingerprinting, describing the technology and its impact on society especially through courtcases and the privacy issues of DNA databases. Chapter 1 briefly explains the basics of DNA Fingerprinting. There are multiple ways in which this technology can be run, each with its own advantages and disadvantages. The aforementioned is explained along with a simple background on DNA and DNA amplification in order to provide enough information to ensure that the reader can follow ensuing chapters.

The reader will learn about the forensic aspect of DNA Fingerprinting in Chapter 2. The chapter goes through the forensic process, starting with the crimescene, and finishing with analysis. Discussion of the biological evidence can be useful at a crime scene and how it is stored to avoid degradation or contamination.

The content on Chapter 3 explains landmark cases in DNA Fingerprinting that serve as a precedence of highly technical evidence in the court system, as in the Frye case. This chapter follows DNA Fingerprinting evidence, and the skepticism, from its initial appearance in the court room to present day. Due to these cases, there are now many standards nation-wide for DNA typing.

Finally, in Chapter 4 the concept of DNA databases is introduced. The audience will come to understand the structure, function, and ethical issues attached with the controversial subject. Although more cases have been solved since the conception of the DNA database, matters concerning an individual's privacy have come to the forefront.

This chapter explains just what kind of material and information can be extracted from one's DNA profile and how that information can affect that person in society.

In conclusion, the various concepts and points presented within the previous chapters are summarized and streamlined. At this point the reader should be able appreciate and understand the impact that DNA Fingerprinting has had on society and the court room, and to formulate their own conclusions about this controversial topic.

PROJECT OBJECTIVE

This project was undertaken to examine the technology of DNA fingerprinting, a new field that has the potential to change the world of forensics as we know it, and to document its impact on society. DNA usage in the courtroom is still very controversial, yet if fully understood, could make this world a very better place. This task was completed by performing extensive research into how DNA is processed into fingerprints, recent advances in DNA collection and storage techniques, and by discussing the legal and ethical issues surrounding the use of this technology.

CHAPTER-1: INTRODUCTION TO DNA FINGERPRINTING

DNA fingerprinting, also known as DNA typing, is used for many different things today from forensics, to paternity testing, to even wildlife management. In forensics DNA typing is a very useful tool in solving crimes and exonerating innocent individuals. Many people in the fingerprinting field prefer to use the phrase DNA typing as opposed to DNA fingerprinting because the fingerprint term is already used to describe hand fingerprints. Often when someone mentions DNA fingerprinting it is confused with the black ink and paper fingerprints. With the exception of identical twins, triplets, etc, DNA type fingerprinting is unique to the individual.

DNA Background

DNA (deoxyribonucleic acid) is among the smallest and most complex structures known to man. “Genetically speaking, humans are 99.9 percent identical. But with 3 billion letters in the genetic code, even that 0.1 percent of variation allows for individuals to have a unique genetic "fingerprint". This gives each of us our individuality, and can be used in a variety of ways, such as linking a bloodstain at a crime scene to a specific suspect; determining paternity, or establishing the identity of people long dead” (Woods, 1999).

DNA is comprised of four chemicals adenine (A), guanine (G), thymine (T) and cytosine (C) (Figure-1). Consistently, adenine is always partnered with thymine, and likewise guanine with cytosine. DNA does not die with the body, which has allowed it to

be used to solve crimes that have baffled investigators for years. DNA is thought to last for millions of years after death depending on the conditions under which it is stored. But no matter how well preserved it is, scientists believe that most DNA deteriorates after 50,000 to 100,000 years. DNA can be found in blood, semen, saliva, urine, hair, teeth, bone and tissue.

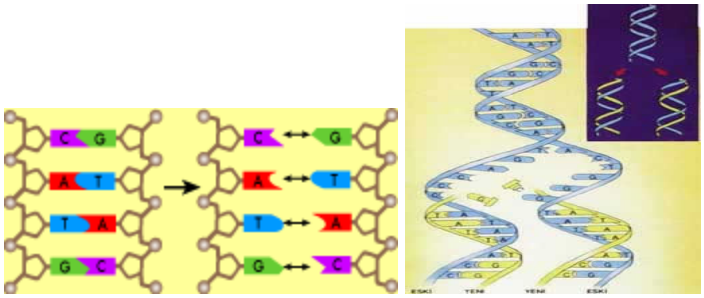
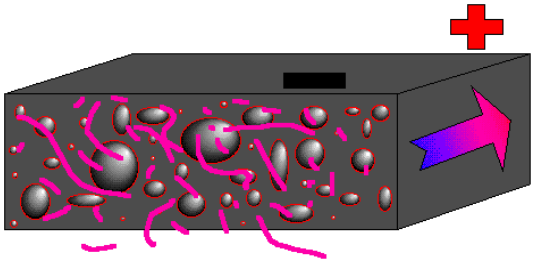


Figure 1a: The pairing of Adenine, Guanine, Thymine and Cytosine Bases in DNA (Learn Genetics, 2006). Figure 1b: The Replication of DNA. The blue DNA strand is separating and the yellow is copying the DNA (The Secrets of DNA, 2006).

RFLP Type DNA Analysis

Two techniques are used to test DNA for forensic purposes, the first is Restriction Fragment Length Polymorphism (RFLP) and the second is Polymerase Chain Reaction (PCR). These assays analyze the difference in lengths between certain DNA fragments known to differ between individuals. The fragment lengths vary due to the presence of a variable number of tandem repeats (VNTR). RFLP is not very sensitive, but is very reliable. It is less prone to contamination because small amounts of contaminating DNA are not amplified in this assay. First the forensic sample is chemically treated to purify the DNA. The chemical used to purify DNA varies with the specific evidence being tested, i.e. bloodstains, saliva, semen, bone, etc. Following DNA extraction, a yield gel is

run to test the sample size and quality. If the quality is good enough, and the size is large enough, the process proceeds. Restriction enzymes are added to the DNA to cut it into pieces. The pieces produced is determined by which enzyme is added to the DNA, each restriction enzyme cuts at different base sequences. The distance between the locations of the restriction enzyme cut sites varies from person to person. The DNA sample is now comprised of millions of DNA bands that vary in length. Electrophoresis is used to separate the DNA bands by size (Figure-2), with the smaller fragments moving farther through the gel as the electric current is applied.



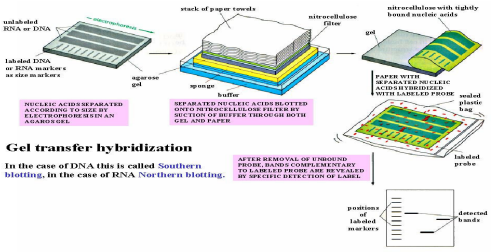


Figure 2a: A cartoon of electrophoresis. The pink lines represent DNA fragments in a gray gel. The arrow shows the direction of movement towards the positive anode.
http://occawlonline.pearsoned.com/bookbind/pubbooks/bc_mcampbell_genomics_1/medialib/method/SDSPAGE/SDSPAGE.html
Figure 2b: Shows the steps in obtaining a Southern Blot. http://amiga1.med.miami.edu/Medical/Werner/lecture11.htm

The DNA sample is inserted into a gel using a needle. If you ever watch "The FBI Files" on the Discovery Channel you may recognize this process. An electric current is passed through the gel. There are two methods of electrophoresis: slab gel electrophoresis and capillary electrophoresis, each give identical results. The electric current causes the negatively charged DNA to move towards the positive anode, the smaller the size the farther it moves in the gel. The larger pieces are hindered from migration, so migrate less distance. At this time the DNA is still double stranded, but the gel is treated with an

alkaline solution to separate the strands. The DNA is then transferred from the gel to a membrane in a process called Southern blotting. Either nitrocellulose paper or nylon paper is laid over the gel, and the separated DNA fragments are transferred to the sheet using a salt solution or electrical current. This process is named after Edward M. Southern who developed the procedure in the 1970's (Khalsa, 2006). Membranes are easier to work with unlike gels which are fragile, dry up, and stick to surfaces. The membrane is then probed to with ssDNA (single-stranded DNA) in a process called hybridization. The ssDNA anneals to its complementary DNA sequence on the membrane. Once this process is finished the membrane sheet is then washed to remove excess ssDNA, the ssDNA which did not anneal with the DNA membrane. Now to the sheet is then exposed to X-ray film in a process called autoradiography to allow the location of the probe to be identified.

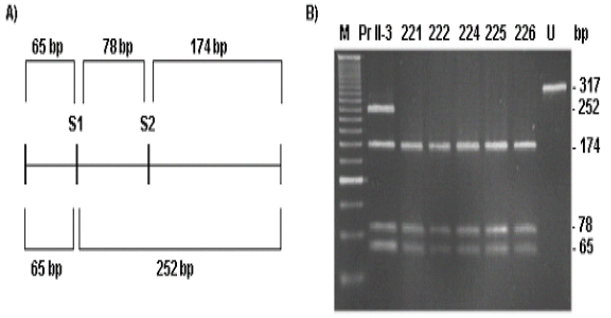
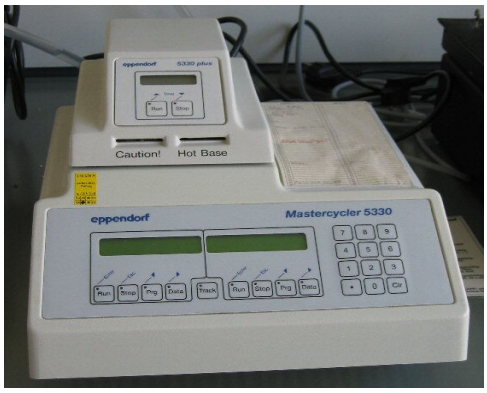


Figure 3: RFLP type DNA analysis (Kabaeva, 2003).

PCR Type DNA Analysis

PCR is the faster of the two DNA analysis processes. PCR is a technology that copies short segments of DNA millions of times in a process that resembles the way in which DNA duplicates itself naturally in the body, sometimes being described as a

biological Xerox machine (Fisher, 2004). But unlike a living organism, the PCR technique can only copy short fragments of DNA, usually up to 10 kilo basespairs (Kb). The PCR test is conducted in a Thermal Cycler machine (Figure-4) which heats and cools the reaction tubes as need. The double helix is separated by heating the DNA between 94-96 degrees Celsius which transforms it into two strands. This step is called denaturing (Wikipedia, 2006). Visualize a zipper being unzipped and having two separate sides for your DNA strands. Added to these two strands is a mixture of primers that target the beginning and end of a specific segment of DNA to be copied. This process is called annealing. Temperature is also very important at this step because if the wrong temperature is used, it will cause the primers to bind to the wrong spot on the DNA, or not at all. Then the DNA polymerase has to copy the DNA strands. This step is called elongation. Back to the zipper analogy, this is equivalent to taking the separated sides and zipping in two new separate strands, leaving you with two whole zippers instead of the original one. This whole process can take less than a half hour. "…the cycle can be repeated 30 or more times. Each newly synthesized DNA piece can act as a new template, so after 30 cycles, 1 billion copies of a single piece of DNA can be produced! Taking into account the time it takes to change the temperature of the reaction vial, 1 million copies can be ready in about three hours" (Bethesda, 1992). The PCR results can now be identified using an agarose gel electrophoresis.



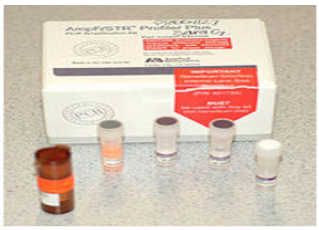


Figure 4a: A PCR machine. http://www.answers.com/topic/pcr-machine-jpg
Figure 4b: Two different DNA detection kits (National Institute of Justice, 2006).

If the sites on the DNA (loci) to be analyzed are short enough, PCR can be used to amplify the signal. So the PCR technique is frequently used to analyze short tandem repeat (STR) regions. In fact, the current FBI protocol for DNA typing analyzes 13 "core loci" that are all STRs. Typically STR/PCR analysis is used first to analyze a sample since it is so quick. Then if the DNA is of high enough size, and in sufficient quantity, an RFLP analysis is used to back up the STR data. The STR procedure works very well with highly degraded DNA, thereby enabling dated cases to be re-opened and possibly solved. Additionally, the speed at which multiple tests can be processed with the use of florescent dyes, lasers, and computers saves a considerable amount of time which can be essential to solving crimes.

Both methods are reliable and accurate. Although it can save time and can test multiple genes simultaneously, the PCR technique requires more individual tests and is disputable in court. Polymerase Chain Reaction does not require as much DNA and is more sensitive than the RFLP version of testing which enables it to be a good preliminary test. RFLP was first initiated in the 1980's making it the older of the two tests. It is not

as sensitive as PCR meaning a higher quality DNA sample is required to produce a result. The older process is labor intensive and allows testing on only one gene at a time. “RFLP testing averages days to complete on multiple genes. PCR technology permits very small samples and partially degraded DNA to be tested. It also shortens the analysis time from days to hours. This technology is the primary reason why DNA testing is increasingly being used today as an investigative tool for law enforcement” (National Institute of Justice, 2006).

The first forensic application of PCR used the HLA DQ-alpha (DQA1) system which was expanded to include additional genetic systems called Polymarker (PM). Although DQa/Polymarker was faster and more sensitive than RFLP, results were less discriminating. For example, random matching profiles might be found in one in several thousand people. In RLFP, the match could be one in several million. However, the current state-of-the-art DNA testing utilizes short tandem repeat (STR) technology which combines the best features of RFLP and PCR. This method examines a subclass of VNTR regions of the DNA molecule that tend to repeat themselves in short, adjacent, or tandem, segments. STR technology can use partially degraded, small quantity DNA and has a very high degree of discrimination. Multiplex' STRs are groups of genetically independent STR markers that can be examined at the same time. These multiplexes have proven to be very successful, lower the probability of a random match to one in several billion, and provide the basis for the local, state and national DNA database entries.

Testing Mitochondrial DNA

In addition to analyzing nuclear DNA, another type of DNA can also be tested: mtDNA or mitochondrial DNA. Mitochondrial DNA exists within mitochondrial organelles in the cytoplasm of a cell. This DNA is used when there is insufficient nuclear DNA for typing. The mtDNA is located in a small cellular structure called a mitochondrion which produces the energy for the cell. "There are hundreds to thousands of mitochondria per cell, and each mitochondrion contains 1-10 mtDNA molecules. The high copy number of mtDNA molecules is one reason why mtDNA is recoverable from hairs and old skeletal remains" (National Institute of Justice, 2006).

When mtDNA is analyzed, the first step is to extract and isolate the DNA from all other material. Then PCR is used to copy the two hypervariable regions, each of which contains 350 of the 16,569 total nucleotides in a human mitochondrial genome. "In the 1980s, scientists discovered that the probability of randomly selecting two people with the same mtDNA type was very low because there are thousands of mtDNA types among humans. Of the 700 nucleotides in the two hypervariable regions, two maternally unrelated people have about 10 nucleotide differences" (National Institute of Justice, 2006).

Mitochondrial DNA is rarely used in court cases because the mtDNA does not change with each offspring. The mtDNA is passed on from the mother because the female egg cells contain mitochondria and the portion of the sperm that enters the egg does not. This means that maternal relatives share the same mtDNA type. Whereas nuclear DNA changes 50% from each offspring because both the male and female

contribute to the DNA to the offspring. A mtDNA test can not be conclusive in the court of law but can be exclusive if the patterns are shown to be different. Also mtDNA is easily contaminated just by breathing on it or touching it.

CHAPTER-2: ADVANCEMENTS IN DNA FORENSICS

"With contact between two items, there will be an exchange". This statement, postulated by a twentieth century forensic scientist, Edmund Locard, is the fundamental idea that drives the field of forensic science. Although not perfected, the analysis of evidence in DNA forensics has been responsible for putting many criminals behind bars, and clearing the name of the accused innocent. When DNA forensics was first used in the 1980's, there were many skeptics and questions to be answered. The idea of convicting a suspect on evidence that, in some cases, is invisible to the naked eye, was absurd and mind-boggling. Even into the early 1990's, there was still some skepticism. For example, in the 1993 court case of Daubert vs. Merrell Dow Pharmaceuticals, the theory and technique behind DNA identification was disputed. They refuted such issues as the validity of applying the standard Restriction Fragment Length Polymorphism (RFLP) technique to criminal samples, proper interpretation of the test results as showing a match, and appropriate statistical determination of the probability of a coincidental match. To quell these allegations, the National Research Council of the National Academy of Sciences convened a committee of forensic scientists involved in law enforcement, and legal scholars. This committee later put out a report recommending the court to take the judicial notice of both theory and common utilization of the testing method to distinguish reliability between different sources of DNA (Kaye and Sensabaugh, 2000). It was around this time, that rules and guidelines were passed that have since been put into place to give forensic DNA analysis more credibility. Before there was no standardized method for the collection and analysis of the DNA evidence

found at the crime scenes. These improvements, discussed in this IQP chapter, along with statistical predictions, have been able to boost the accuracy and reliability of DNA testing.

When working with the DNA samples prepared from physical evidence, a limiting factor of analysis was the DNA length, which had be high molecular weight, 100-200 kilobasepairs (kb) long. However, with the more sensitive RFLP method, which has been used in laboratories starting in the 1990's, samples only had to be 10-20 kb. Then with the advent of PCR and STR analysis (discussed in Chapter-1), the most common method of DNA analysis used today, the DNA could even be partially degraded and still provide useful information. Also, the analysis now has built-in positive and negative controls which help to further validate tests (Kirby 1990).

Advancements in quality controls have come a long way as well. Each lab must have periodic external audits to verify they are up to date, with clearly written protocols, equipment calibration and maintenance are current, and lab safety reviewed constantly. The lab workers themselves have to undergo extensive training to ensure that there is consistency from worker to worker, and less of a chance of human error. Finally, working conditions are constantly monitored to ensure samples will not degrade, experiments will not be ruined, and results will be produced effectively and efficiently (Kirby 1990).

Figure 1: An example of a DNA fingerprint. Gel blot comparing DNA bands among different populations and profiles. http://www.istockphoto.com/file_closeup/what/society/sciences/183541_genotyping.php?id=183541

Mathematical formulas have been developed especially for DNA application. With these mathematical formulas, they show that having an incorrect match would be very doubtful. The current system put in place by the Federal of Investigation (FBI) analyses 13 main core loci which indicate that it would be very unlikely to have an incorrect random match. In fact, with the short tandem repeats (STR) loci method currently used, the probability of a random match is one in 6×10^{14}. The courts in the United States have come to recognize the appropriateness of assigning probabilities to DNA matches from the appropriate population. Once there is a match between the unknown and suspect profile, the criminal has been identified, provided that the random probability is small (Cecil et al., 1995).

Suggestions were made in a 1991 *Science* article by Richard Lewontin and Daniel Hartl (Lewtontin 1991) that the multiplication rule (multiplying the allele frequencies for each core locus tested) for calculating match probability may in fact be futile. They challenged the assumption that major racial groups are genetically homogeneous, and claimed that the "Caucasian," "Black" and "Hispanic" races were synonyms for an amalgam of genetically diverse subpopulations, especially in an immigrant country like the United States, where there are going to be genetic substructures expected due to a number of population and immigration variables. Statisticians have been able to since disprove the paper by various demonstrations of the multiplication rule in relation to the major racial groups targeted in Lewontin and Hartl's paper (Krawczak and Schmidtke, 1998). In addition, as more DNA profiles have been added to the FBI CODIS DNA database over the years, more information has become available on genetic diversities within racial subgroups, allowing far more accurate predictions to be made (to be

discussed in Chapter-5). DNA databases have been established in countries world-wide, including the United States, Great Britain, Australia, and Japan. With the collection of hundreds of thousands of criminal DNA profiles, investigators have a good starting point for comparisons in many cases, including those when minority suspects are involved.

DNA Evidence Sources

At a crime scene it is important that the investigators and detectives use their experience to be thorough enough to gather all the relevant evidence that they can, but at the same time collect the evidence that is the most relevant. If an investigator does not gather enough physical evidence, then the whole case could be compromised. On the other hand, if the team gathers too much evidence, then the lab could be backed up for weeks just trying to work through it all and analyze it effectively. Therefore, an experienced team is the best way to ensure that appropriate amount evidence is collected. It is also necessary to limit the number of people in and out of a crime scene to keep the chance of contamination or evidence alteration as limited as possibly (Byrd 2000).

There are two kinds of DNA investigators can find and use at a crime scene. Nuclear DNA can be found in hair roots, body tissues, and bodily fluids such as blood, semen, and saliva (Figure-2A). Mitochondrial DNA, used in tracing ancestry through the female line, helpful if there are charred remains, is contained in naturally shed hairs (Figure-2B), hair fragments, bones and teeth ("DNA Forensics" 2004). If there has been a homicide, the deceased individual will give a lot of evidence about him/herself, but the evidence might also point to the offender.

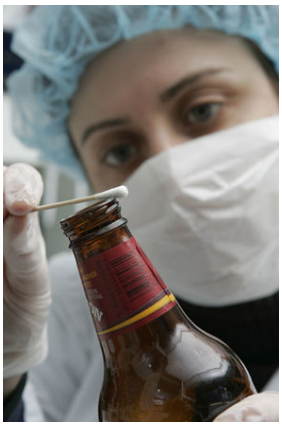


Figure 2a: Saliva off a bottle can serve as a source of DNA
http://www.genetictechnologies.com.au/index_general.asp?menuid=130

Figure 2b: A naturally shed hair is another one of the many sources for DNA that can be found at a crime scene.
http://www.flickr.com/photos/27286898@N00/125264508/

After taking a DNA sample from the victim to serve as a negative control in analysis, investigators look for evidence such as pulled hair that will implicate the criminal. Finding blood at a crime scene can be very useful in an investigation, whether it is the victims and can be used to act as a negative control, or used to find the offender. Blood stains, in the presence of a chemical called luminol, will turn bluish-green under a black light (Harris 1995) (Figure-3). The downside of using luminol is that it also bleaches DNA and can destroy other evidence at the scene, so the luminol should be used after taking samples for DNA analysis. However the use of luminol is still a very useful last resort when investigators have hit a wall trying to find DNA evidence.

Figure 3: Luminol under ultraviolet light indicates blood stains (Harris 1998).

When blood is found at a scene, there are certain ways of handling it to guarantee that it remains undamaged and uncontaminated. Right at the scene, if the blood stain is wet, it should be absorbed onto a clean cotton swab and placed directly into purple vacutainers with ethylenedianminetetraacetic acid (EDTA) a chemical to prevent DNA degradation, and store at 4^{o}C (Schiro 2001). If it is going to be stored for a long period of time, the sample should be aliquotted into screw cap polypropylene tubes (Figure-4A) and frozen at -20^{o}C or -70^{o}C (Budowle et al., 2000). If the blood stain is dry by the time the investigators arrive at the scene, the object that the stain is on should be cut up and brought directly to the lab. If the object to too big to do so, investigators can make due by absorbing the stain with a clean cotton cloth with distilled water, letting it air dry and then placing it in a package. These are steps that are taken to make certain that the blood sample arrives to the lab unchanged and hopefully, no degradation has occurred. If other evidence is also found, measures must be taken to guarantee that those specimens are as intact as possible upon arrival at the lab.

Figure 4a: A sample of containers used in DNA evidence collection. http://www.dojes.com/images/140.jpg

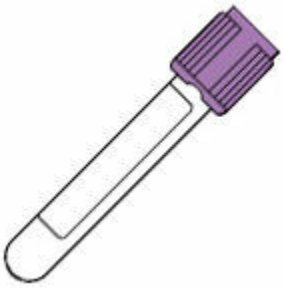


Figure 4b: Screw-cap polypropylene caps prevent blood from degrading. http://pulmolab.com/laboratory/lab_supp/vacutainers/lavender_top.html

Preventing DNA Contamination

DNA contamination can destroy a case, as far as physical evidence collection is concerned. If the DNA found in the specimens is exposed to DNA from another person, the quality and quantity of DNA could be compromised, along with the case. While at the scene, it is very important for investigators to use non-powdered gloves because some powders can interfere with DNA extraction and analysis. While moving from sample to sample at the scene, it is necessary to change gloves every time, as well. This limits the amount of cross-contamination there can be from each sample (Koblinsky 2005). The effect of this contamination, whether occurring at the scene, or later in the lab is less of a concern with RFLP analysis that does not amplify small amounts of contaminants, but can be a significant problem with STR/PCR analysis in which small amounts of contaminating DNA can provide a strong signal. All biological evidence is packaged into paper bags and envelopes. This type of packaging allows air to flow through, drying wet evidence, as wet samples tend to degrade quickly. Plastic containers are good for packaging tissue samples such as skeletal muscle that will not be stored for more that two hours prior to DNA extraction in the lab. Once in the lab there are guidelines, briefly mentioned at the beginning of this chapter, in place to avoid evidence being lost, mishandled, or destroyed. A simple but important step is to label everything that the evidence is contained in, as well as the time and date. If a mislabeling occurs, then crime samples could potentially get confused with known samples and produce a false positive ID (Kaye 2000).

To further ensure that the DNA evidence is as sterile as possible, lab technicians are ordered to use specific equipment and handle the evidence a certain way. A laminar

flood hood is used to maintain a sterile environment for the sample and avoid airborne contamination (Koblinsky 2005). The location that the evidence is handled is separate from the location that the PCR takes place to make sure that the amplification of a sample has not been cross-contaminated with another. Additionally, all steps leading to PCR should be done individually with absolutely no multi-tasking, analyzed, and unanalyzed DNA is to be kept separately. Use separate glassware pipettes, gel apparatus and other possible sources of DNA transfer (Kirby 1990). Since DNA evidence can often make or break a case, security measures are in place as well. All refrigerators are to be locked during off duty lab hours, and a close watch on all of those in and out of the lab should be performed at all times ("Evidence Submission Guidelines 2005).

Figure 5: Laminar Flow Hoods are used when DNA is handled to provide a sterile environment. http://www.pemed.com/lab/hoods/hoods.htm

Preventing DNA Degradation

The combined efforts of the investigators and laboratory technicians will hopefully yield an uncontaminated evidence sample, however DNA degradation can also be a factor. DNA degradation can render a sample un-analyzable. A major cause of DNA degradation could be a microbial contaminant due to the capability of their enzymes to destroy nucleic acid polymers and convert the genomic DNA into useless short nucleic acid fragments, called oligonucleotides (Koblinsky 2005). While in

transport from the crime scene to the analyzing facility, it is of utmost importance to have no heat, moisture, or ultraviolet radiation, which contribute to the ruin of the sample. Crime scene investigators have to work fast when a possible DNA sample is found on leather or denim because there are chemical compounds found in these materials that have powerful DNA degrading capabilities (Koblinsky 2005). When samples are collected, it is beneficial to keep the DNA as concentrated as possible, stored in TE buffer, and held in airtight tubes. This buffer has Tris-HCl and EDTA that works to hinder DNAase activity which in turn slows down degradation. The sample can be stored at -70^{o} C until further use.

CHAPTER-3: LANDMARK DNA COURTCASES

The introduction of DNA evidence into the courtroom is not a straightforward process. As with any complex technology, legal precedents must be set for evidence that is often too complex to be easily understood by a jury. The purpose of this chapter is to discuss some of the landmark DNA court cases that set precedence for admitting technical evidence.

Frye v US, 293 F 1013 (1923)

The rule that is in place today called the "Frye Rule" derives from a famous 1923 case involving the offer of expert testimony on a technique called the systolic blood pressure deception test. This test was almost like a lie detector test, measuring whether the defendant was "telling the truth" by monitoring the systolic blood pressure of the accused. In the Frye case, James Frye was placed on trial for murder. He maintained that he was innocent from the time of his arrest. From the start of the trial, his attorney suggested that Frye take a lie detector test to determine whether he was telling the truth regarding his innocence. His attorney asked the court to accept Frye's results as evidence to support his plea of innocence. The results, he said, proved Frye's innocence, and the stage was set for trying to admit an unproven technology into the courtroom.

Although the technique was very new at that time, his attorney said he had an expert witness (Frye v. United States, D.C Cir. 1923). The expert witness was William Marston, an attorney and psychologist who was very well qualified. Marston had done a great deal of research on how changes in the body's internal systems can correlate to

lying. “He claimed that the test measured whether the defendant was telling the truth by monitoring his systolic blood pressure” (Borders, 1989). The systolic blood pressure goes up and down depending on how hard the ventricles of the heart are contracting. Marston argued that fear always produces a rise in systolic blood pressure, and that lying, accompanied with the fear of detection, will raise the blood pressure.

The judge of the trial in the District of Columbia excluded Mr. Marston’s testimony stating that the science of “deception testing” was too new to be admitted. But Mr. Frye’s lawyer took the case to the Court of Appeals of the District of Columbia. Frye was a far reaching decision. Frye hearings, arguments for and against such unproven evidence, were held without the jury present, and the admissibility was determined by the judge. Experts testified as to the general acceptance of the evidence or technique. The Appellate Court ultimately ruled that the systolic blood pressure test was too new, and had not been proven scientifically, and upheld the guilty ruling of the lower courts. Soon after this appeal it should be noted that another man admitted his guilt in the case against Frye thus proving Frye’s innocence. Out of all of this it was ruled that when applying the Frye standard, a scientific principle has to gain general acceptance in the scientific community in order to be admitted into court. This was called the general acceptance rule, and it has been used in various cases, and in various forms, for the last 60 years.

COLIN PITCHFORK, 1986

In 1983, in Narborough, England a 15-year-old schoolgirl was found murdered and raped. Semen was found at the scene of the crime and was taken from body of the victim Lynda Mann. The DNA was found to belong to a person with type A blood

group, and enzyme profile. This sample matched only 10 per cent of the adult male population, with no other leads in the case or evidence available, the case was placed into the unsolved category, although it was left open.

Three years later in 1986, the body of 15 year old Dawn Ashworth was found strangled and sexually assaulted in the same town. Her body was found on a walking path in town. Police believed very strongly that the person who killed Lynda Mann was also responsible for this murder and brutal rape. Police searched a database for men with a history of sexual offenses. Semen samples recovered from Dawn's body revealed her attacker had the same type-A blood type as Lynda's murderer. A young man named Carlton Hayes was questioned by police becoming the prime suspect, after questioning he revealed previously unreleased details about Dawn Ashworth's body. Further questioning led to his confession, but he denied any involvement in the murder of Lynda Mann (Evans, 1996).

Officers were convinced that Carlton Hayes had committed both murders, so they contacted Professor Sir Alec Jeffreys at Leicester University who had developed a technique for creating DNA profiles. Dr Jeffreys, along with colleague Dr Peter Gill and Dr Dave Werrett of the Forensic Science Service had jointly published the first paper on applying DNA profiling to forensic science. In 1985, they were the first to demonstrate that DNA could be obtained from crime stains, which would prove vital in this case.

Dr Gill said:

> *"I was responsible for developing all of the DNA extraction techniques and demonstrating that it was possible after all to obtain DNA profiles from old stains. The biggest achievement was developing the preferential extraction*

method to separate sperm from vaginal cells – without this method it would have been difficult to use DNA in rape cases."

Using this technique, Dr Jeffreys compared semen samples from both murders against a blood sample from the suspect, which conclusively proved that both girls were killed by the same man, but not the suspect. The police then contacted the FSS to verify Dr. Jeffrey's results, and to decide which direction to take the investigation (Hare, 1993).

Peter Gill said:

"Since the technique had not been used in criminal casework before, the FSS were asked by the police to confirm Dr Jeffrey's conclusions. Accordingly, we carried out further tests and indeed demonstrated that the prime suspect could be excluded."

Carlton Hayes became the first person in the world to be exonerated of murder through the use of DNA testing. The police then decided to undertake the world's first DNA intelligence screening. Every adult male in the three surrounding counties, a total of 5,000 men, were asked to volunteer to provide samples of their DNA, they were given an option of providing blood or saliva samples. Blood grouping was performed, and DNA profiling carried out by the FSS on the 10 per cent of men who had the same blood type as the killer (Cook-Deegan, 1994). In this dragnet, the murderer almost escaped again by getting a friend to give blood in his name. However, this friend was later overheard in a local bar talking about the switch and that he'd given his sample pretending to be Colin Pitchfork. Colin Pitchfork (Figure-1) a local baker was arrested, and his DNA profile matched the semen from both murders. In 1988 he was sentenced to life for the two murders, and is still in prison to this day. The impact that this conviction had on our judicial system was enormous, and the importance of this landmark case is incredible in the fact that it has forever changed the way police conduct investigations at

crime scenes. Items that were thought to contain no evidentiary value, can now be the most important piece of evidence in the case whether to exonerate the innocent or convict the guilty.

Figure-1: A Picture of Colin Pitchfork. The first murder conviction based on DNA evidence.

Paul Eugene Robinson

Police Detective Peter Willover of the Sacramento Police department had a decision to make which would prove very difficult. With the statute of limitations looming on a rape case he was investigating, he worried because Police departments routinely destroy evidence believed to be outdated, the time was coming to destroy the evidence taken from the second story rapist, evidence that Willover had been hoping to see used in court. He was having difficulty holding out hope so, he called the DA's office a few days before the statute expired and asked Anne Marie Schubert, who was a sexual assault prosecutor, if she had any bright ideas about salvaging the old cases police believed were all tied to the same predator.

Schubert told Detective Willover that there was an earlier case out of Milwaukee that she had heard about. She had read an article about a prosecutor in Milwaukee named

Norman Gahn, who had filed for a warrant under the name of John Doe. It was a warrant against a suspect that they had in three rapes which was about to fall victim to the approaching six-year statute of limitations that Wisconsin had. Gahn brilliantly did not name a suspect or identify him by physical characteristics commonly used when acquiring a warrant, but instead identified him solely using his DNA code which had been left behind at the scene of his three rapes. This approach was groundbreaking, enabling the clock on the statute of limitations to cease for the time being, but the prosecutors did not know if their idea would work until someone was arrested and successfully prosecuted. With this as the only option left for Detective Willover, Schubert said she would like to see the same attempt made with his case in an effort to salvage the evidence and put a rapist in jail.

In August of 2000, the sexual assault prosecutor, filed the John Doe case:

> *Number 00F06871, "THE PEOPLE OF THE STATE OF CALIFORNIA vs. JOHN DOE." The charges listed the suspect as an "unknown male with Short Tandem Repeat (STR) Deoxyribonucleic Acid (DNA) Profile at the following Genetic Locations, using the Cofiler and Profiler Plus Polymerase Chain Reaction (PCR) amplification kits: D3S1358 (15,15), D16S539 (9,10), THO1 (7,7), TPOX (6,9), CSF1PO (10,11), D7S820 (8,11), vWa (18,19), FGA (22,24), D8S1179 (12,15), D21S11 (28,28), D18S51 (20,20), D5S818 (8,13), D13S317 (10,11), with said Genetic Profile being unique, occurring in approximately 1 in 21 sextillion of the Caucasian population, 1 in 650 quadrillion of the African American population, 1 in 420 sextillion of the Hispanic population.*

This is where Paul E. Robinson (Figure-2) comes into this case which set a precedent that will likely affect the way police do their work forever. He was a 31-year-old ex-con who had been arrested in 1998 for a violation of his parole. Robinson had finished serving a lengthy sentence for a several burglaries when he was spotted by

sheriff's deputies loitering around private property, and he was arrested. A month after his arrest, Robinson pleaded no contest to the loitering charges. A check of his criminal history revealed that he may have been responsible for one of the crimes listed in the state's DNA and Forensic Identification Data Base and Data Bank Act of 1998, so they took blood and saliva samples from Robinson and sent the samples to the lab. He had one qualifying conviction on his rap sheet, spousal abuse, but it was a misdemeanor charge and state law said it must be a felony to take the DNA samples.

Figure-2: Picture of Paul Eugene Robinson, the first conviction of someone using ONLY DNA evidence.

In September 2000, three weeks after the John Doe warrant was issued and Robinson's DNA sample had been sent to the lab, Willover received a call from the lab stating that the DNA from Robinson triggered a match with the warrant issued. The problem was that Robinson's DNA was put in the database by mistake, because he had only committed a misdemeanor not a felony, but luckily state law does allow for mistakes when they are made accidentally. A new warrant was filed listing Robinson, by name

and description, and he was arrested the day the warrant was issued. His arrest meant the use of old DNA, so a John Doe warrant would be tested in court for the first time.

The Fourth Amendment states that suspects named in arrest warrants be identified with reasonable particularity. The Fourth Amendment of the U.S. Constitution and California law see eye to eye on what is necessary for a suspect to be identified. So with DNA now universally accepted as the number one means of identification, Schubert believed she was on solid ground with that part of her case, and that she was going to be able to take Robinson to court for the unsolved rapes, and successfully prosecute him. No two people have the same DNA, so it appeared to be a slamdunk case, but there was another problem that threatened the success of the whole case.

The law in California requires the identifying information to be on the face of the warrant. But the genetic coding is so long and its use in these cases so new, computer software used to type arrest warrants didn't include the correct forms to accommodate the information. So, in Robinson's case, the warrant identified the suspect only as John Doe, "male, black." The genetic identifiers were nowhere on the warrant. That prompted Robinson's attorney, to claim in pre-trial motions that any black male in town could be arrested based on that information. And even if the warrant were filled out properly, his lawyer argued it raised a much larger legal issue that never had been tested.

> "Can we allow a prosecutor's office, the DA, an office of the government, to go around that (statute of limitations) law and circumvent it to stop the clock?" www.da.saccounty.net

Many people even civil libertarians as well as some staunch advocates of DNA evidence have questioned the validity of extending or abolishing statutes of limitations in rapes and other violent crimes, as California and a host of other states have done or are considering. For one thing, these advocates have warned, statutes of limitations are as old as English common law, and have been used to protect defendants against witness's whose memories may not be the same after the passage of time.

Lawyers pointed out, that John Doe warrants were only asked for and issued in stranger rapes. There were not any date-rape or consensual sex issues in their cases in which personal ID would be required.

> *"I believe in statutes of limitations," Gahn said. "You don't want to have stale charges and you want to make sure memories are fresh. But DNA is different. Every one of the cases we've filed is a stranger dragged off the street or raped after her house was broken into, and when you have semen on a vaginal swab I think someone will remember dragging someone off the street and into a garage or something and inserting his penis in her. There is nothing the least bit vague about any of this."*

In defending her case, Schubert argued that the computer version of her John Doe warrant directed any law enforcement officer reading it to an additional set of "remarks" that did include Robinson's full genetic coding and an instruction to contact Det. Willover. Understandably Shubert was nervous about how the prosecution would go in this case.

According to Superior Court Judge Tani G. Cantil-Sakauye, who denied Griffin's motion to dismiss the charges because the warrant was invalid, the attack on the validity of the warrant was "hypertechnical" (www.alicapatterson.org). In explaining her ruling, the superior court judge said she first considered the case "straightforward and really

simplistic in nature, and that the arrest warrant on its face lacked particularity in describing the subject John Doe." According to the judge, that made the warrant invalid, which meant the statute of limitations would have passed and Robinson could not be prosecuted.

The judge said that upon further review and study of case law, she concluded something altogether different. "The spirit of the Fourth Amendment and the particularity requirement is met in this particular case given the information readily available," she said in ruling from the bench after an all-day hearing on Feb. 23.

Arrest warrants are specific to protect against the wrong person being arrested, she said. Police would be directed to Robinson's genetic coding in the remarks section of the paperwork and computer forms accompanying the warrant, so, she said, no one could be arrested based on the coding alone. There would be less of an abuse of the process of arrest in this case because no reasonable officer would arrest any male black who refused to give him his name, then call him John Doe and bring him in, the judge said in a courtroom that included the suspect, the victim and her friends and family, as well as other lawyers wanting to witness the hearing. The judge ruled that with the advances of science DNA was unalterable, and therefore a conclusive piece of evidence. The judge was quoted as saying that based on what I heard about the input of information fields and computer systems, I don't think we've caught up with that concept yet, but I would submit that it is the most accurate description we have to date, the judge said.

Like the John Doe cases in Milwaukee, the Sacramento case drew national attention, and even Gahn called the first affirmation of John Doe DNA rape cases a

landmark. Defense attorney Griffin, meanwhile, said he would appeal the ruling all the way to the U.S. Supreme court. A California appellate court and the California Supreme court have already refused to hear his appeal.

CHAPTER 4: DNA DATABASES

The DNA database is the "ultimate weapon against crime" (Krawczak and Schmidtke, 1998). Without them, the impact of DNA profiling as a means of positive ID would be limited. Starting in the early 1990's, the United Kingdom lead the database revolution, headed by the Forensic Science Services (Krawczak and Schmidtke, 1998). The United States soon followed the trend in 1994, when the Federal Investigation Bureau of Investigation (FBI) began to develop what has become the world's largest database on a national scale- inclusive of DNA profiles of both convicted sex offenders and those convicted of other violent crimes. Thanks to guidelines and suggestions established by the Technical Working Group on DNA Analysis Methods (TWGDAM), Codis (Combined DNA Index System) was created (Adams, 2000). A few years later, in 1998, the national portion of the DNA index went online (FBIs Combined DNA Index System Program). CODIS, in general, is software that is capable of connecting forensic laboratories nation-wide to help solve crimes. It accomplishes this major task by electronically sharing DNA profiles, making it possible to figure out relationships between crimes in different cities, and capture criminals that live in other states. There are three levels within CODIS according to DNA Profiles access (Figure-1). The most substantial level is the National DNA Index system (NDIS) which allows CODIS to be linked across the nation for access to the DNA profiles stored within the CODIS Program (Adams, 2000). The State DNA Index System (SDIS) and the Local DNA Index System (LDIS) are the two lower levels. All three levels are connected via CODIS to help in solving crime. If forensic laboratories stay within CODIS regulation established by the

DNA Advisory Board, a result of the DNA Identification ACT and the TWGDAM, there are Federal funding grants to facilitate access the DNA profiles from the CODIS system. When there is an investigation with no suspects based on other evidence found at the crimescene, chief investigators turn to CODIS to try to find a matching profile, whether it be at a local, state, or national level. Should there be a match, the case has a high probability of being solved, in some cases even when there is no other physical evidence. For reasons discussed in Chapter 2, such as population probability, a match does not mean a definite identification on the sample. Conversely, if there is no match to known offenders, then the profile will be searched for in the crime scene index. This index also stores the profiles of unidentified biological evidence from crime scenes. Even with these unidentified profiles, police are often times able to figure out any relationship between cases (Adams, 2000).

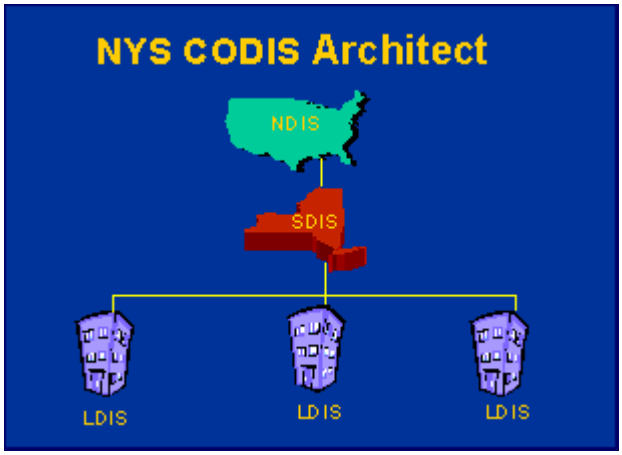


Figure 1 : Structure of the New York System of CODIS, similar to states nation-wide.

http://www.troopers.state.ny.us/Forensic_Science/Modern_Forensics/CODIS/

Usefulness of DNA Database

The DNA database trend has been extremely handy in solving cases where there is a substantial amount of biological evidence left at the scene. With the DNA Fingerprinting revolution, valuable data has been able to be obtained that contributes to

placing criminals at the crime scene. As the years pass, and many profiles are created, it only makes sense that there would have to be some sort of storage system so that unsolved cases, could perhaps be solved in the future, serial criminals can be identified, and justice be served. Since CODIS is a system that is only as useful as the number of profiles it contains, the more profiles that are store in it, the better chance of a match there is. That is why it is important for crime scene investigators to consider all the biological evidence that could potentially be at a scene. Figure-2 lists the number of cases benefited by DNA evidence per state.

Once a profile is created, even if there is no match from within the CODIS database, the unidentified profile should be stored so that the next time the same profile is searched for, a relationship can be established between the two crimes. When collecting DNA samples not from a crime scene, but from a live person, there are very strict privacy laws which dictate that CODIS is prevented from expanding to include every single offender. The subject of privacy laws will be discussed in further detail later on in this chapter.

Figure 2: "Investigations Aided" is a metric that tracks the number of criminal investigations where CODIS has added value to the investigative process. Up to date through May 2006. http://www.fbi.gov/hq/lab/codis/aidedmap.htm

State	Investigations Aided
Alabama	1,197
Alaska	158
Arizona	1,127
Arkansas	126
California	1,509
Colorado	281

Connecticut	151
Delaware	6
District of Columbia	171 (FBI Lab)
Florida	4,458
Georgia	722 - (27 US Army Crime Lab)
Hawaii	2
Idaho	5
Illinois	4,007
Indiana	536
Iowa	104
Kansas	234
Kentucky	213
Louisiana	388
Maine	60
Maryland	531
Massachusetts	361
Michigan	1,541
Minnesota	478
Mississippi	5
Missouri	1,061
Montana	13
Nebraska	14
Nevada	250
New Hampshire	16
New Jersey	342
New Mexico	554
New York	4,032
North Carolina	403
North Dakota	4
Ohio	2,489
Oklahoma	108
Oregon	1,083
Pennsylvania	839
Rhode Island	2
South Carolina	546

South Dakota	4
Tennessee	129
Texas	1,317
Utah	38
Vermont	0
Virginia	3,391
Washington	342
West Virginia	8
Wisconsin	804
Wyoming	5

DNA Database Contents

The recently decoded human genome is made up of millions of basepairs that contribute to an individual. What many people do not know is that 95% of the human genome is in fact, junk! This major percentage is comprised of non-coding amino acid basepairs that do not code for anything, but is the main target of forensic investigators since it varies between individuals. The other 5% of the genes are responsible for coding proteins that create our appearance, and is not useful in investigations since the sequence of such critical genes is conserved between individuals. Junk DNA is a long chain of Short Tandem Repeats (STR) that fabricate the DNA fingerprint of an individual, with the number of STR units differing from one person to the next (Curran, 1997). An STR varies in length on a visible level in the assay protocols and can serve to make or refute DNA matches ("Junk", 2004). As discussed in Chapters 1 and 2, the FBI typically analyzes 13 core loci sites on the DNA and uses the number of STR at each site as an

identification tool (Figure-3). Therefore, the probability of two people having the same DNA is very small, reducing the amounts of random incorrect matches.

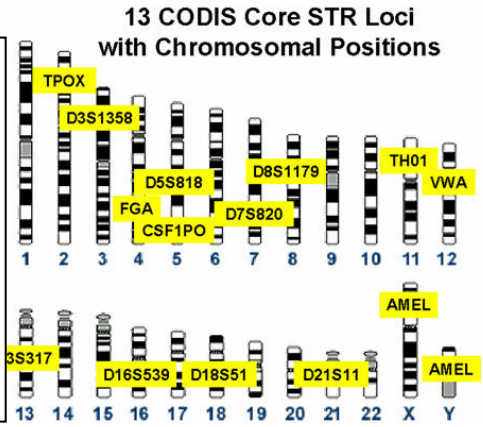


Figure-3: The FBI analyzes 13 different loci within each DNA sample to help identify individuals.

http://www.cstl.nist.gov/div831/strbase/fbicore.htm

DNA Databases and Privacy

So much benefit has resulted from the establishment of the DNA database system that one may wonder why everyone is not required to donate some sort of DNA sample so that the number of profiles in CODIS can increase, as well as the probability of matches (Cecil, 1995). Privacy laws are the very reason the source of profiles for CODIS is limited. These laws were enacted to protect the rights of citizens. So if the DNA profile of a person is known, a countless number of characteristics can be known about that individual, even some that that person, him or herself, is unaware of. For example, many genetically predisposed diseases can be identified by looking at an individual's DNA sequence, which could in turn jeopardize an innocent person to lose health insurance or job opportunities. If one is kind enough to comply and provide DNA to create a CODIS profile, then the potential detriment that he or she would face does not seem fair. Other aspects such as legitimacy of birth, behavior, and sexual orientation

could also be revealed via DNA profiling ("DNA Forensics", 2004). Essentially everything that creates the person's personal identity can be revealed from a simple blood sample causing much unease. On top of that, researches have yet to prove that DNA databases do, in fact, prevent crime due to fear of being caught (Krawczak and Schmidtke, 1998). However for our purposes, it is important to realize that genetic predispositions can not be deduced from the type of information included in a standard forensic analysis of 13 core loci. So if laws are enacted mandating the destruction of original DNA sample once the forensic loci are analyzed, much of the Privacy Right debate is solved. Although some argue that every time the CODIS System is accessed, a person's privacy is invaded (Mayer-Schönberger, 2003), this argument does not hold up in light of no medical information being present in CODIS.

Those Required to Provide DNA Samples

Who has DNA in the system now? Maybe if there was something done to make DNA databases a perfect law enforcement tool, allowing only certain people to view it, people would warm up to the idea. However, there would still be an issue with violating the assumption of innocence, which is present in the legal systems of many countries (Krawczak and Schmidtke, 1998). In some states, they argue that all arrested individuals should provide a DNA sample for testing since after all, when you are arrested for DUI they take your normal fingerprints, even before proving your guilt. Is that any less an invasion of privacy, especially if the DNA sample is destroyed so no medical genetic information can be obtained.

Sex offenders and violent criminals fall into the category of required submission in most states, where there is neither privacy laws nor the assumption of innocence, so they must submit a DNA sample. It is more of a priority to keep these criminals from committing other crimes by locking them up, than to preserve Privacy Rights which many agrue they gave up the moment they committed the crime. It seems more of a humane thing to do than subjecting society to live in fear with these offenders wandering the streets. There are different profiles and criminals that take priority. If a common thief and a repeat murderer were being sought after, it is reasonable to say that the murderer would take higher priority over the thief, with more invested effort to find him or her. Once captured, it is absolutely necessary to get a DNA sample from the killer, and it is not viewed as "wrong" by society. Should the murderer repeat the crime, he or she can be quickly identified and hopefully recaptured. With the previously given DNA sample combined and the indicative biological evidence found at the scene, it should be enough to gain a warrant to raid the suspect's home to recapture or even obtain more DNA samples.

It is a bonus to have the profile of many violent offenders as well. Criminals do not always start out as killers, in fact, research reveals that many murderers start off with smaller crimes such as burglary or a drug offense (Adams, 2002). Therefore, if samples are taken when these smaller crimes are committed, then the likelihood that a later murderer can be identified is increased. Many states have so much faith in this research that they have moved to taking DNA samples from non-violent offenders as well. The order is such that a murderer's profile can be accessed every time, but that of a thief can only be accessed if the initial search of the convicted murderer's database is fruitless. To

up numbers within the database, a couple states, including California, have started collecting samples from every arrestee (Steinhardt 2003). It has been questioned if this is a bit extreme, as a speeding ticket could also be a ticket into the CODIS system, but arrestees are already asked to provide normal fingerprints.

Another extremity that has occurred in the Southern state of Louisiana where police took to the streets to collect DNA samples in hopes of finding a suspect for a case. They collected over one thousand DNA samples from people that either lived near the area of the crime or looked similar to the given suspect description, without any "real choice". Following this DNA collection, many lawsuits were filed by those donors that were found innocent, demanding that their samples be destroyed. The American Civil Liberties Union (ACLU) stepped in and claimed that these sorts of collections did not seem voluntary, but rather, an invasion of privacy that donors were subjected to. This DNA collection is also said to be very adverse to an individual as it goes against the Fifth Amendment protection for citizens against self-incrimination (Koblinsky, 2005). As previously pointed out in this chapter, with a non-forensic through analysis of DNA authorities can see heredity disorders, sexual orientation, and predisposition to crime to violent acts, but not with forensic information from the core loci. It has been characterized that males that have an extra Y chromosome-known as XYY syndrome- are more prone to violent and criminal behavior, and could suffer from a genetic stereotype used for discrimination against them in prisons (Annas, 2003). However, studies have shown that there is not a one hundred percent correlation between violent behavior and XYY syndrome, thus limiting the grounds for discrimination (Steinhardt, 2003). It is without question that the DNA of convicted felons is found in the NDIS, causing many to

claim that prisoners should be treated humanely and not as "lab rats" subjected to genetic tests without their consent.

Chapter Conclusion

This controversy over who should provide DNA to CODIS does not seem to have an end in sight. The invention of DNA Databases has brought about some major improvements to DNA fingerprinting technology in general, and has helped solve thousands of crimes. Even though the investigators are only interested in the "junk" portion of the human genome for identification, this "junk" has many capabilities that can jeopardize an individual's health insurance and privacy if medical loci are analyzed, so it is very important to enforce analysis of only forensic loci not containing any medical information, and to force destruction of the sample post-analysis to prevent any subsequent capture of medical information. It is tough to draw the line of who should have a DNA profile within CODIS system to help in identification. On one hand, the more Profiles there are, the more potential hits. However, on the other hand, whenever a profile is searched for, their privacy is compromised. Also, how many rights should criminals have? Do they have a right to privacy even though they are often outcasts of society? What about the rights of the person murdered by the criminal? All of these, and many more, are issues that court systems world-wide are going to have to sit down and figure out so that the optimal benefit can be achieved from the DNA Database System.

CONCLUSIONS

DNA fingerprinting is a very important part of society today. It is used in many different fields from helping to solve crimes, to helping find the unknown parent of a child. It is more prevalent in cases of crime, at crime scenes to gather information to find a solution to the case.

DNA forensics has been useful in many legal cases to help release the innocent, or to jail the guilty. It is hard for many to imagine that something unseen to the naked eye can help solve a murder crime. As the technique is used more frequently, more have become aware of the accuracy of DNA forensics and have stopped questioning the certainty of it when it is done correctly. At a crime scene, there is now standardized methods of how to correctly collect the DNA evidence so that it can be properly used in the courtroom. Also, those people that work in the labs undergo intense training to be sure that they know how to run proper controls, and minimize contamination. It is very important that each DNA sample is removed properly, treated properly, and stored at the right temperature to ensure the outcome is impeccable.

Using DNA evidence in court is not as easy as one would assume. It is a very complex process that involved a series of landmark courtcases that established precedence for accepting technical evidence. DNA databases serve as an important tool in helping solve crimes by matching crimescene DNA to that of convicted offenders, or by determining whether different crimes were performed by one individual. Although some individuals argue that privacy rights are violated when an individual contributes their DNA to a database, the research performed in our project indicates that no medical

information is included in forensic DNA databases. So long as legislation is enacted mandating the destruction of the original DNA sample (from which is might be possible in the future to determine medical predispositions), much of the privacy rights opposition is silenced.

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