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DNA FINGERPRINTING

An Interactive Qualifying Project Report

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ABSTRACT

The purpose of this IQP was to use the topic of DNA fingerprinting as an example of a new technology with a strong impact on society. The technical part of the project investigated what DNA is, how DNA fingerprints are performed, and recent standardized protocols for DNA evidence collection, while the societal part of the project investigated landmark court cases that set legal precedence for admitting technical evidence (including DNA) in U.S. courts, and the ethics of DNA databases.

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PROJECT OBJECTIVE

The purpose of this IQP was to investigate the topic of DNA fingerprinting as an example of a new technology with a strong impact on society. By investigating what DNA is, and how DNA fingerprints are performed we hoped to become familiar with the technical aspects of a technology that has been called the greatest forensic tool in the history of forensic science, and to explain the technology in layman's terms that might be understandable to a broad audience, such as prospective jurors. By investigating the latest protocols for DNA evidence handling we hoped to underscore the importance of preventing evidence contamination, documenting evidence chain of custody, and preventing DNA degradation, as the public was made painfully aware during the O.J. Simpson "Trial of the Century". By investigating landmark court cases we hoped to document the ups and downs of DNA evidence admissibility in U.S. courts to point out that it was not a straight forward process, as with any new technology. And finally, by investigating the controversial topic of DNA databases, we hoped to describe in layman's terms why we need such databases for solving crimes, and to help alleviate the public's fears about the databases containing medical information.

Chapter-1: DNA Fingerprinting Techniques

DNA fingerprinting is a relatively new technique that has revolutionized forensic science. The process was first discovered in England in 1985 and is based on the fact that the DNA of each person is unique. In 1992, DNA fingerprinting was approved by the U.S. National Research Council as a reliable identification technique, which rapidly launched the usage of DNA fingerprints in court cases as evidence. Scientists use common lab procedures such as Southern blotting, and Polymerase Chain Reaction to create DNA fingerprints (Dolan DNA Learning Center). The purpose of this chapter is to describe the techniques of DNA fingerprinting, and their applications.

A DNA fingerprint is a unique barcode pattern of information derived from assaying a subject's DNA. Each person has a unique sequence of DNA base pairs which allows a person to be identified by examining their genetic material. The fingerprint itself is a distinct pattern that resembles a barcode. It can be displayed directly on a gel, or on a nitrocellulose sheet visualized by x-ray film (Brinton and Lieberman, 2004).

DNA Fingerprinting Applications

DNA Fingerprinting has a wide variety of applications; the most prevalent one is its usage as evidence in court cases. DNA Fingerprinting is a facet of a science known as forensics, the usage of science and technology to aid in criminal investigations. In criminal cases, jurors have to be certain of their decision or else they could be sending an innocent man or woman to a lifetime of prison or even to his or her death. Forensic scientists can examine crime scenes, and collect evidence that contains genetic material

which can be used to create a DNA Fingerprint which in turn, will confirm or deny whether a suspect was present at a crime scene. DNA Fingerprinting in conjunction with other evidence can assure that the accused person will receive the correct verdict.

Another use of DNA fingerprinting is paternity testing. Women who are pregnant, but are unsure of who the father is because they have had multiple sexual partners can use DNA fingerprinting to discover the father of the child. DNA fingerprinting has successfully been used to prove fatherhood for purposes of facilitating the payment of delinquent child support payments. Also, for rape victim cases, DNA fingerprinting can help determine whether a suspect had sex with the victim.

Recently, scientists have been aiding the government by identifying the remains of soldiers. For example, there are approximately 2000 servicemen still listed as missing in action from the Vietnam war. With DNA fingerprinting, scientists can extract genetic material from soldiers remains, and compare it against family members of the missing soldiers. During the fall of 1999, 9 of the 13 members of a helicopter crash were identified which helped bring peace to family members and loved ones. (Riverdeep, 2000)

An additional use of DNA fingerprinting exists in molecular archaeology. This new field allows ancient genetic remains to be analyzed to determine species, blood lines, or gender of ancient species. For example, students from the University of Pennsylvania studied archaeological remains from King Midas' tomb to discover the meal that was served at his funeral feast. Through molecular archaeology, researchers discovered there were around 100 guests at the feast, dining on a spicy stew of barbequed lamb or goat, and lentils. Researchers also uncovered the mourners were drinking honey mead, mixed

wine, and barley beer. (Marter, 2000). Molecular archaeology allows us to understand our history in a much richer way. Differences between ancient and modern species can be revealed by comparing modern and ancient genetic material which will give us a much better view of our past.

DNA Structure

DNA, which stands for **d**eoxyribo**n**ucleic **a**cid is the genetic material of the cell. The majority of DNA is termed "junk DNA"; it doesn't code for any proteins, or have a known function. Coding DNA (the DNA that isn't "junk") controls the production of proteins and is therefore, responsible for the biochemistry of that organism. Most of an organism's DNA is identical to other organisms of that species, but there are areas that are different called, polymorphisms. DNA is composed of nucleotide subunits; which consist of deoxyribose (a sugar), a phosphate group, and one of four nitrogenous bases; thymine (T), guanine (G), adenine (A), and cytosine (C). These subunits bond to each other covalently to form strands of DNA. The nitrogenous bases form hydrogen bonds which link the DNA together. The bases are specific in their bonding; adenine only bonds to thymine, and guanine only bonds to cytosine (Hartwell et. al, 2000). These bonds form the naturally occurring double helix structure shown in Figure 1 as red and blue strands. Note the T-A and G-C base-pairs as rungs on the DNA ladder.

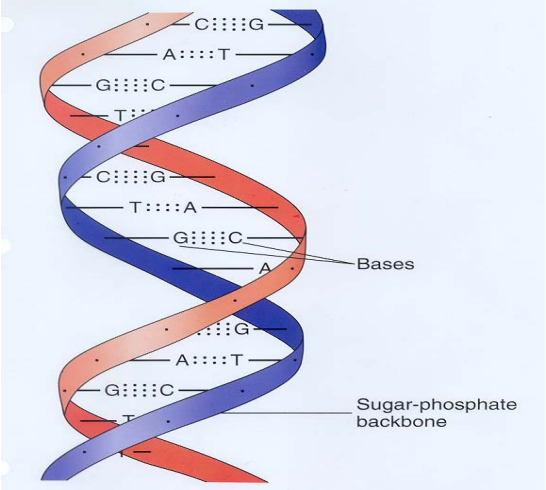

Figure 1: Structure of DNA.
Figure from Index of Chemistry, 2004.

A chromosome, which is found in the nucleus of the cell, is the structural unit that is composed of a long strand of DNA, and proteins. Different species have varying numbers of chromosomes; for example normal humans have 46, whereas *Drosophila melanogaster*, the common fruit fly has 8. Chromosomes are separated further into subunits called genes; sections of the chromosome that code for specific functions or characteristics. In fruit flies, for example, the X chromosome, a sex-determining chromosome, contains the gene that controls eye color (Kimball, 2004).

In forensic DNA analysis an entire person's DNA is not analyzed. A person's genome contains about 3 billion DNA bases, and only recently has the first human genome been sequenced (Human Genome Project, 2003). In forensics where hundreds of thousands of samples are analyzed in the U.S. annually, only specific sites (or loci) on the DNA molecule are analyzed, especially those sites shown to be unique between individuals. A locus is a specific location on a chromosome, for example the location of a genetic marker, or the beginning of a gene. Forensic loci frequently are not genes but

instead exist in introns, the DNA that does not code proteins, or in junk DNA between genes.

STR Fingerprints

Certain non-coding loci contain short tandem repeats (STR). These STR are short DNA sequences that are usually 3-5 base pairs long and repeat multiple times. For example on human chromosome 7 the sequence "GATA" can repeat from 6 to 15 times (The Biology Project, 2000). The advantage of STR analysis is that the STR repeats are short enough to be amplified by PCR analysis. In 1990, the FBI initiated a project called CODIS (combined DNA index system) which standardizes the loci that scientists utilize for STR analysis. This standardization assures quality control, increases the statistical confidence levels in the results, and lowers the risk of error when analyzing DNA. The 13 CODIS loci are shown below:

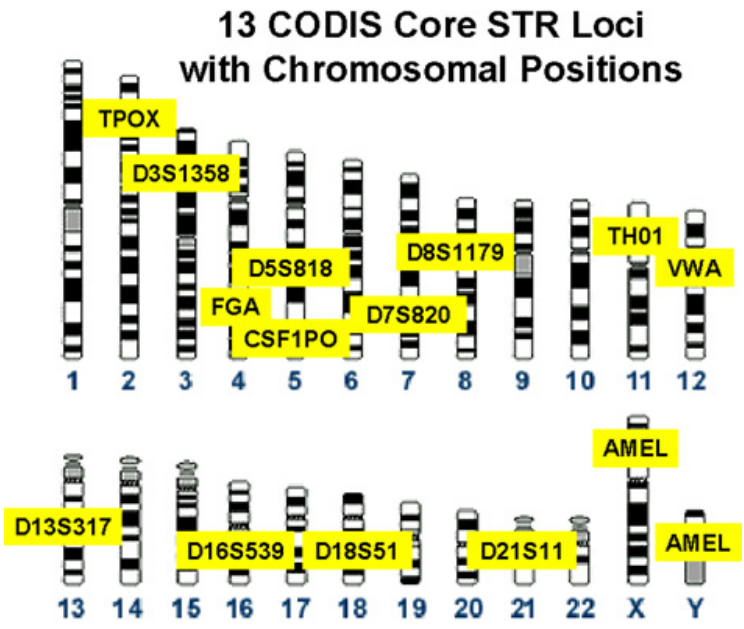

Figure 2: The 13 CODIS Core STR Loci.
From: The National Institute of Standards and Technology, 1997.

Polymerase chain reaction (PCR) is a new technique that allows a short known DNA sequence to be replicated resulting in millions of copies in a small amount of time. PCR requires several materials: target DNA, primers, DNA polymerase, and a thermal cycler. The target DNA is the DNA that will be amplified. Primers are short artificial strands of a DNA sequence which bond to the beginning and end of the target sequence and allow replication to occur. The primers are designed to anneal to specific STR loci. The primers anneal to the STRs, then the DNA polymerase extends the primers and finishes complementing the base pairs by synthesizing the rest of the DNA. Thus the PCR process involves a series of repeated 3 steps:

1) denaturation of template DNA to make single strands (usually at 95˚C),

2) primer annealing to STRs (usually at 55˚C), and

3) DNA elongation (usually at 72˚C).

Usually the 3 steps are repeated 35-50 times to amplify the STR DNAs. The machine that automatically performs these repeated cycles of heating and cooling is termed a thermocycler (Dolan DNA Learning Center, 1994).

STR analysis allows DNA amplification by PCR and therefore, can be performed on trace amounts of forensic genetic evidence. STR analysis also has the advantage of being simpler to run than VNTR's because no probe hybridization step is needed to visualize the length of the STR bands amplified by PCR, simple electrophoresis accomplishes this. An example of an STR fingerprint is shown in Figure-3. In this case, the DNA samples in lanes 1 and 5 look similar.

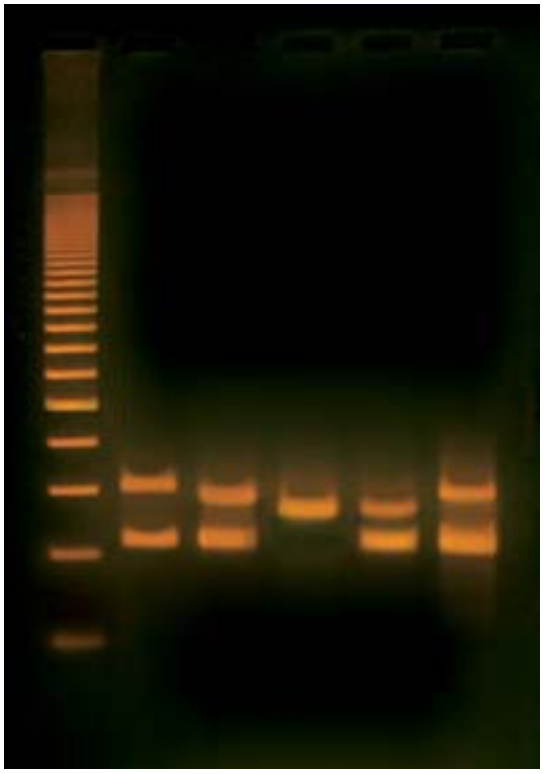

Figure 3: STR Fingerprint. Figure from
The Biotechnology Education Company, 2004.

The first step in running a STR DNA fingerprint is isolating the DNA from the rest of the cellular material. This separation can be done chemically, by applying a large amount of pressure, or by using a detergent wash. A large amount of DNA is necessary to run a VNTR fingerprint, but an STR-PCR fingerprint can be run on trace amount of DNA. The PCR results in many copies of specific STR loci from the original DNA strand. One of the main advantages of STR-PCR analysis over VNTR's is the STR bands do not need to be cut by restriction nucleases to be sized on a gel, they are already short. And because they are amplified, they can be directly seen on the gel.

The amplified short STR fragments are then sorted by gel electrophoresis. This process is quite simple; the DNA is added to a gel which then undergoes an electrical

charge. The top of the gel receives a negative charge, while the bottom of the gel received a positive charge. Due to DNA's negative phosphate groups, the DNA will travel towards the bottom; smaller pieces moving faster, thus getting farther down the gel. Once the electrophoresis is completed, the smallest pieces of DNA will be the farthest down the gel, whereas the largest pieces of DNA will be at the top. The gel is then stained with methylene blue which allows one to analyze the fingerprint (Rubin, 2003). The result (Figure-3) appears very similar to a bar code.

RFLP's and VNTR's

Bacteria produce extremely useful proteins called restriction enzymes that are used to cleave foreign DNA that enters the bacterial cell. These enzymes cut DNA at specific nucleotide sequences. Scientists take advantage of this recognition process in many ways, including the ability to detect DNA polymorphisms. A polymorphism is a change in a nucleotide sequence at a specific site in two individuals. These polymorphisms might create a new restriction site, or destroy an old one, which can be detected by restriction digestion. Restriction fragment length polymorphisms (RFLP) are changes in the lengths or patterns of DNA fragments cut with specific restriction enzymes that result from the presence of different DNA recognition sites. RFLP patterns vary between individuals because of our unique base pair sequence. This RFLP analysis technique can be used to run a DNA fingerprint to identify someone genetically (Raven & Johnson, 2002).

Loci on human chromosomes contain a variable number of tandem repeats (VNTR); repeating segments of DNA base pairs that are usually 9 to 80 base pairs long.

These VNTR's occur in introns (the DNA between coding DNA within a gene) or also in the "junk DNA" between genes, and differ in length between individuals (Tandem Repeats, 2001). The disadvantage of performing VNTR fingerprints is they utilize relatively large amounts of DNA for analysis. Because VNTR fragments are too large to amplify by PCR, this process contrasts with STR's which allow the use of PCR to amplify the DNA. VNTR analysis is also more complex than STR analysis since probe hybridization is often used to visualize the bands of interest, while simple electrophoresis is used in STR analysis. Figure-4 below shows a VNTR fingerprint. The bands are the result of the radioactive probe that binds to specific sites on the DNA. The bands can then be compared across different lanes to look for similarities. In this example, the DNA analysis from the crime scene bloodstain matches suspect-3.

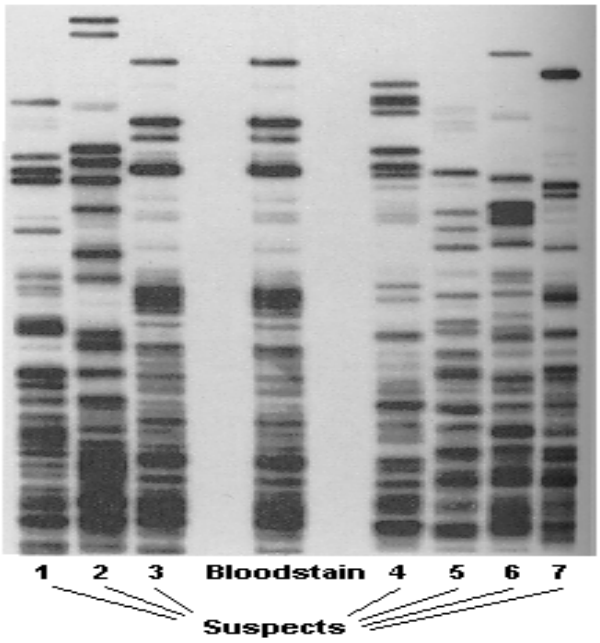

Figure 4: A VNTR Fingerprint.
From: Short Tandem Repeat DNA Internet Database, 1997.

VNTR/RFLP analysis differs from STR analysis, largely in the last step. Instead of directly analyzing STR bands on a gel, for VNTR analysis the DNA sample is cut with restriction enzymes, then transferred to nitrocellulose membrane, and hybridized to a specific VNTR probe. These probes are radioactive DNA sequences that are designed to complement specific VNTR sequences of nucleotides. The probes are introduced to strands of DNA on the membrane that have been denatured, and thus are single stranded. The membrane-probe mixture is then shaken which allows the probes to bind to their complementary strands. The membrane sheet can then be exposed to x-ray film to examine where the probes bound. The results are similar to the dyeing method, and result in a bar-code like product.

To conclude, the process of DNA fingerprinting, while intimidating at first has become a routine, common practice in law enforcement and scientific communities. This amazing breakthrough has transformed our court systems and strengthened our laboratories. This amazing technique is surely a great asset to our society.

Chapter-2: DNA Forensics

Prevention of DNA Contamination

The usage of DNA evidence in the courtroom has exonerated innocent prisoners, while sending the guilty to a lifetime of incarceration. There is no doubt that DNA evidence is one of the most powerful tools in forensic science. Many cases have been solved because of this useful tool. Child support payments have been made, fatherhood has been confirmed, criminal offenders have been brought to justice, and countless other successes have occurred due to DNA fingerprinting. However, using such a powerful tool requires great care and consideration. The OJ Simpson "trial of the century" focused the nation's attention on implementing rigorous procedures for handling DNA to prevent contamination, and for documenting which individuals had access to the samples. These errors led to multiple organizations dictating new guidelines and suggestions for forensic evidence handling, collection, and transportation. These guidelines support correct forensic analysis, and help evidence acceptance in the courtroom. The purpose of this chapter is to describe some of these new recommendations.

Contamination of DNA can have horrible consequences on DNA analysis; it can lead to evidence being discarded in a court case, or incorrect results. Contamination occurs when outside material is introduced to the sample, for example another person's DNA or a chemical that was spilt. Some guidelines to prevent these errors are highlighted below:

- Avoid excessive exposure to heat or humidity – refrigerate/freeze if possible
- Never handle evidence with bare hands

- Never allow two items of evidence to come into contact with each other
- Air-dry evidence completely before packaging
- Package evidence in paper sacks or envelopes (avoid plastic bags)
- Package each item separately
- Ship evidence with dry ice or leak-proof ice packet (sample must remain dry)

(Reliagene Technologies INC., 2002).

Following guidelines, systematic procedures, and using care during evidence collection and transportation greatly lowers the likelihood of contamination. The U.S. National Institute of Justice suggests that these following steps be taken to avoid contamination:

- Wear gloves. Change them often.
- Use disposable instruments or clean them thoroughly before and after handling each sample.
- Avoid touching the area where you believe DNA may exist.
- Avoid talking, sneezing, and coughing over evidence.
- Avoid touching your face, nose, and mouth when collecting and packaging evidence.
- Air-dry evidence thoroughly before packaging.
- Put evidence into new paper bags or envelopes, not into plastic bags. Do not use staples.

Evidence collection and transportation are not the only places where mistakes can be made though. Lab technicians must use great care and follow strict guidelines in order to process the DNA material correctly so it can be submitted as valid evidence. Although many precautions are taken, human error still exists. The National Research Council recommends that evidence be divided into multiple samples; this supplies forensic scientists with back up samples in case contamination or other mistakes subsequently occur. The NRC also recommends analysis is conducted by unbiased lab technicians that have a low error rate to assure accurate and fair results. (Wittmeyer, 2004).

For DNA evidence to be accepted, it is critical that you can prove that the evidence you collected is that of a suspect and not of someone else. This can be done by collecting elimination samples, DNA of people who were at the crime scene but are not suspects. This assures that the evidence being submitted is that of a suspect, and not someone else. For example, in rape cases, DNA samples from the victim's recent consensual partners are often collected to eliminate them as possible contributors of DNA (National Institute of Justice, 1999).

Being prepared and knowledgeable are the most important parts of DNA evidence collection. It is crucial to have all the right equipment to complete the task at hand and know different collection methods for specific types of evidence. For example, large blood stains should be collected with sterile gauze or cotton cloth, allowed to air dry, and then refrigerated or frozen immediately. In the case of dried blood stains, collection depends on the material to which the blood has adhered to. If the blood has adhered to clothing or a small object, it should be wrapped in clean paper and sent to the laboratory. On a larger solid object, such as a table, the stain should be scraped with a clean knife

onto clean paper, and then placed into a collection envelope and shipped to the lab. For seminal stains on clothing or other cloth materials, allow the evidence to air dry, then wrap the evidence in paper bags and ship it to the laboratory as soon as possible. For sex offense cases the victim should be examined by a physician as quickly as possible. If hair is found, it should be collected with tweezers, and sent to the laboratory in a labeled envelope.

It is important to treat all evidence with great care and caution. When collecting evidence it is crucial to wear gloves and to change them often. This will protect the evidence from being contaminated by your skin cells, hair, sweat, or any other contaminant that may be transferred from you to the evidence through direct or even close contact. Another necessary precautionary step is using disposable sterile instruments, or instruments that are cleaned thoroughly before and after handling the sample. Also, the collector of the evidence must use caution to avoid touching, talking, sneezing, or coughing in the vicinity of the DNA evidence.

Companies such as Arrowhead Forensic Products sell kits (Figure-5) that contain everything that is necessary for collecting DNA evidence. "The kit contains sterile water in individual pipettes, sterile swabs, disposable tweezers, sterile gauze, collection threads, coin envelopes, SealGuard minis, and comes packaged in a plastic box" (Arrowhead Forensic Products, 2004). This kit will allow evidence collectors to gather the evidence they need without contaminating or destroying it.

Figure 5: DNA Evidence Collection kit.
Figure from Arrowhead Forensic Products (2004)

In some cases evidence won't be as easy to collect; for example in some cases the crime scene has been "cleaned" by the criminal. A crucial tool of forensic scientists is a chemical called Luminol ($C_8H_7N_3O_2$). Tiny blood particles that can not be seen with the naked eye will cling to most surfaces for years. When these surfaces are treated with luminol, and the lights are turned off, any blood that is present will emit a bluish-green light for a short period of time (Figure-6). It is important to note that this luminol treatment of a crime scene could potentially damage other evidence, so dispensing of luminol over surfaces should be done sparingly. Luminol is usually dispensed with a spray bottle after the chemical has freshly been mixed with Hydrogen Peroxide as a solvent (Harris, 1998).

Figure 6: Luminol Uncovering a Bloody Footprint.
Figure from: Harris, 1998.

Sources of DNA

A large assortment of evidence can be used to collect DNA. Remnants including sweat, skin, hair, blood, mucus, semen, saliva, urine, and other tissues are commonly left behind at crime scenes. The National Institute of Justice (1999) lists these following examples as common pieces of evidence that include genetic material:

Evidence	Possible Location of DNA on the Evidence	Source of DNA
baseball bat or similar weapon	handle, end	sweat, skin, blood, tissue
hat, bandanna, or mask	Inside	sweat, hair, dandruff
eyeglasses	nose or ear pieces, lens	sweat, skin
facial tissue, cotton swab	surface area	mucus, blood, sweat, semen, ear wax
dirty laundry	surface area	blood, sweat, semen
toothpick	Tips	saliva

used cigarette	cigarette butt	saliva
stamp or envelope	licked area	saliva
tape or ligature	inside/outside surface	skin, sweat
bottle, can, or glass	sides, mouthpiece	saliva, sweat
used condom	inside/outside surface	semen, vaginal or rectal cells
blanket, pillow, sheet	surface area	sweat, hair, semen, urine, saliva
"through and through" bullet	outside surface	blood, tissue
bite mark	person's skin or clothing	saliva
fingernail, partial fingernail	scrapings	blood, sweat, tissue

Table 1: Common Sources of DNA Evidence.
From: The National Institute of Justice, 1999.

A suspect trying to hide his or her identity with a ski mask will fail with the assistance of forensic sciences. If this ski mask is found as evidence it will most likely contain hair, saliva, sweat, skin and perhaps mucus. DNA samples can be collected from these remains, which will allow investigators to complete a successful DNA fingerprint. Other evidence such as weapons, articles of clothing, used cigarettes, stamps, bottles, used condoms, and even fingernails can be used to attain a DNA sample (National Institute of Justice, 1999).

With the advent of forensic sciences, crimes that were mysteries for years, or even decades, can now be solved. For example, in 1993 Mia Zapata was beaten, raped, and strangled to death. Her family and friends mourned for years because the killer could not

be found. The only evidence found on her body was saliva, which forensic detective's collected. Ten years later in 2003, the case went from cold to hot when they analyzed the saliva sample and found viable DNA. They compared this DNA to a government database and found a suspect who was questioned and eventually incarcerated (CBS News, 2004). In most cases though, detectives aren't as lucky; they do not have frozen evidence that they can analyze ten years later. In some cases, detectives or scientists have to rely on artifacts that are decades, centuries, or even millennia old. Amazingly, viable DNA can be extracted from such aged material. Scientists have the most success extracting old DNA from bones, and teeth. Recently, scientists have had success extracting DNA from hair and fur from a bison, dated to be 64,800 years old in June of 2004 (Discovery News, 2004).

DNA Storage

Storing DNA requires low temperatures, and dark places that are not humid. Low temperatures protect the DNA from degradation and allow the samples to be used many years after originally taken. Purified DNA in aqueous solutions can be stored for up to 3 years if stored at 4 degrees Celsius. For storage of time periods longer than 3 years, it is suggested that the sample be stored at -70 degrees Celsius. Storage of blood is slightly more difficult. Short term storage of blood requires temperatures of 4 degrees Celsius, but if 5 days at that temperature is exceeded the DNA will start to degrade. Long term storage of blood requires temperatures of -80 degrees Celsius to assure the DNA remains intact (Center of Genetic Medicine, 2004).

Companies such as Whatman profit from customers who want inexpensive long term DNA storage. Whatman produces a chemical treatment known as FTA that allows DNA to be stored on a small card at room temperature. Samples such as cheek cells, or small amounts of blood are applied to the card, the chemical treatment lyses the cell, and purifies and protects the DNA from microbial and environmental degradation. Storage on this card is estimated at multiple decades, and has proven to last 12 years (Whatman, 2004).

DNA Degradation

Degradation is the breaking down of DNA into smaller pieces. DNA degradation can be caused by a number of factors including extreme heat, UV rays, certain chemicals, moisture and humidity. Transporting and storing DNA evidence requires much care, but is relatively simple. The DNA must be kept dry, out of the sun, and at cold temperatures. If these needs are not met the DNA will start to degrade.

To conclude, DNA fingerprinting has become a strong staple in our judicial system, but to assure that the evidence is considered valid a lot of care and effort must go into evidence collection and handling. From the crime scene to the lab, all of the members who work on a case must use extreme care and follow guidelines diligently so that the evidence can be submitted and help the court system come to correct conclusions.

CHAPTER-3: LANDMARK DNA COURT CASES

Now that we have discussed the *technology* of DNA fingerprints and forensics, we can focus our attention on the *impact* of this new technology on society. This amazing technology has been described as the greatest forensic tool in the history of forensic science, and as such it has widespread applications in the courtroom. However the acceptance of any new technology in the U.S. legal system is not always straightforward. New technnologies are allowed only after a series of landmark cases that establish legal precedence for its acceptance. In this chapter we describe some of the U.S. court cases that affected the use of DNA evidence.

Frye v. United States, 1923

In 1923, James Alphonzo Frye was convicted of second-degree murder. However the case was appealed to the Supreme Court of the District of Columbia based on the defense that Frye had previously passed a "lie detector test proving his innnocence". Lie detector tests were new at that time, and were based on the theory that increases in systolic blood pressure result from a suspect's fear of being detected. The supreme court questioned whether this new technology was *generally accepted* in the scientific community, and whether scieitific studies had been completed to support Frye's argument that changes in blood pressure accurately demonstrate whether a test subject is giving honest answers. The Supreme Court eventually ruled the lie detector technology was not generally accepted, and that the district court had properly excluded this evidence from the earlier case. The court explained:

> Just when a scientific principal or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone, the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs (Frye v. United States, 1923).

Thus the original guilty verdict stood (Frye v. United States, 1923). Three years after the court ruled against his appeal, Frye was released from his life sentence because another person confessed to the crime. However, this *general acceptance* criterion was used for several decades in subsequent U.S. cases, eventually becoming known as the *Frye Standard or Frye Test*, which set the bar to determine whether evidence has a valid scientific basis (Bernstein, 2001).

> Determining "general acceptance" according to the Frye standard is a two-step procedure: (1) identifying the particular field(s) into which the scientific principle or discovery falls and the relevant scientific community; and (2) determining whether that community accepts the technology, principle, or discovery (Coleman and Swenson, 2003).

Virtually every federal and state court addressing the general acceptance standard has adopted the Frye test. However, the Frye test is a rather limited, conservative standard that is hard to actually achieve in the courtroom, therefore several courts subsequently adopted the more lenient Rule 702 (see below). DNA evidence did not achieve the Frye standard until the case of U.S. v Two Bulls, 1990.

Federal Rule of Evidence 702, 1975

Because the Frye Standard for accepting new technologies was difficult to prove in the courtroom, in 1975 Congress adopted the more lenient Federal Rules of Evidence

702 (Federal Rules of Evidence Online, 2003; Moenssens, 2004). These rules are clearly descriptive, and when determining the admissibility of scientific evidence, they stress *helpfulness, reliability, and relevance* (not general acceptance). In particular, Rule 702 embodies a more flexible general relevance test for admissibility of opinion testimony by expert witnesses not allowed by the Frye test.

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case (Federal Rules of Evidence Online, 2003).

In effect, this rule reformed the Frye standard relying more on the *reliability* of the technique used instead of its general acceptance, and making it less strict as to the type of person who could appear in court as an expert. Federal Rule of Evidence 702 provides a uniform approach to be followed by every trial court to assess the reliability and helpfulness of expert testimony.

U.S. v. Downing, 1985

In 1985, John W. Downing was charged with mail fraud, wire fraud, and interstate transportation of stolen property. Downing was accused of leading a scheme to defraud several vendors by a group of individuals calling themselves the Universal League of Clergy. The prosecution's case consisted primarily of 12 eyewitness testimonies claiming Downing was the man they knew as Reverend Claymore who had defrauded them. The defense argued that eyewitness testimony was generally unreliable, and wished to use a psychologist as expert. However, the court denied the defense

request, ruling the psychologist's testimony did not meet the *helpfulness standard* of Rule 702. The jury found Downing guilty of all counts, except the interstate transportation of stolen property, and convicted him in the U.S. District Court for the Eastern District of Pennsylvania (U.S. v. Downing, 1985).

This case took an interesting twist when Downing appealed his conviction claiming that eyewitness testimony is accurate. Judge Becker of the U.S. Court of Appeals for the Third Circuit held that the district court was wrong in its decision to exclude the psychologist's expert testimony, and remanded the case back to the district court with instructions to conduct an evidentiary hearing on the admissibility of expert testimony. If the district court found the expert testimony should have been included, a new trial should be granted. If not, then the guilty verdict would be reinstated. After the hearing, the district court declined to admit the psychologist's testimony, and reinstated the original guilty verdict (U.S. v Downing, 1985). The court reinstated the conviction on the grounds that: (1) the psychologist's testimony did not carry with it a sufficient degree of reliability to aid the jury in reaching an accurate resolution, (2) admitting the evidence would overwhelm, confuse, or mislead the jury, and (3) the expert testimony would not be of value because the eyewitness encounters in this case were numerous and of extensive duration.

The Downing case established the standard that when there is a serious question regarding the reliability of evidence, it is important for the court to exercise an evidentiary *relevancy hearing*. This pretrial hearing may be the most efficient procedure that a court can use to determine reliability, and this procedure outweighs the Frye general acceptance standard (Harvard Law Publications, 1999).

Andrews v. State of Florida, 1988

Tommie Lee Andrews was a suspect in more than twenty assaults in the Orlando area in 1986. His luck ran out in February of 1987 when, during another rape, he left his semen at the crimescene as usual, but this time DNA fingerprinting was applied to the sample. Scientists from Lifecodes Corporation in Valhalla, New York, were able to connect Andrews to the crime with DNA identification evidence. Dr. Michael Baird of Lifecodes claimed there was a one in ten billion chance that the match of the rapists' and Andrew's DNA was a coincidence (Andrews v. State, 1988). But DNA testing had not yet been used in a U.S. criminal case. Before the prosecution could use the results of the DNA testing, it had to go through an evidentiary hearing. The court applied the rigorous Frye standard of admissibility, and the new scientific technology passed the test of general acceptability in the scientific community. Although DNA analysis had not quite established a sound reputation, it proved to be scientifically reliable in method, theory, and interpretation, and positively reviewed by peers (Andrews v. State, 1988). After a long and intense hearing, the judge admitteed the DNA evidence into Andrews's first trial, but would not permit the impressive statistical evidence that the prosecution could not validate. The first trial ended in a hung jury.

At the retrial, the strong DNA evidence was again admitted. But this time applying the *Downing relevancy test* and the *Rule 702 reliability test*, the court also admitted the statistical data. The DNA evidence was accompanied by Andrew's regular fingerprints left on a windowsill, and his identification by the most recent victim in a photolineup. It took the jury only a short time to conclude Andrews was guilty. Andrews

was convicted on October 20, 1988, in the Circuit Court of Orange County of aggravated battery, sexual battery, and armed burglary of a dwelling (Andrews v. State, 1988). Tommie Lee Andrews became the first person in the U.S. convicted of a crime based on DNA evidence. Andrews appealed the verdict, but on November 22, 1988, the original convictions and sentences were affirmed (Andrews v. State, 1988).

Soon after that trial, Andrews DNA was found to match that of other several other victims in the Orlando area, and his prison sentence went from an initial twenty-two years for rape, to over a one hundred years for serial rape. Following Andrews v. State, DNA testing can now more easily be applied to future cases involving sexual assault and other crimes of violence. Such evidence is especially important in such cases since reliable eyewitness identification is often not available (Coleman and Swenson, 2003).

People of the State of New York v. Joseph CASTRO, 1989

The case against Joseph Castro was the first time the admissibility of DNA evidence in U.S. courts was critically questioned (Coleman and Swenson, 2003). Joseph Castro, a thirty-eight year old Hispanic, was accused of murdering his pregnant neighbor, twenty-year old Vilma Ponce, and her two-year old daughter (People v. Castro, 1989). Both victims were stabbed to death in their Bronx apartment building. In July of 1987, Lifecodes Corp. analyzed a bloodstain on Castro's watch for a match to the victims. The DNA from the blood of Ponce matched that on the watch. Lifecodes Corp. testified that the frequency of the resulting DNA profile in the Hispanic population was approximately one in one hundred million. Regardless, Castro swore the blood was his own, and the prosecutors wanted to counter attack with the DNA evidence.

Ignoring the 1988 Andrews ruling based on the Downing relevancy test, and the Rule 702 reliability test, the New York Supreme Court investigated the admissibility of DNA tests in a pretrial hearing applying the rigorous Frye standard. Thousands of pages of expert testimony accumulated from the pretrial. After twelve weeks, the court completed its legal examination of DNA tests in general, and the methods employed by Lifecodes Corp. in this particular case (People v. Castro, 1989). Four of the expert witnesses, representing both the prosecution and the defense, met for an unusual review of the DNA evidence after they had already testified. These four expert witnesses put in writing two pages worth of inadequacies of the DNA evidence and the legal procedures for evaluating the evidence. Although the document was not accepted as evidence in the pretrial hearing, two of the expert witnesses provided testimony on its material. In August 1989, Judge Gerald Sheindlin decided on the admissibility of the tests. A three-pronged test was developed to determine whether DNA evidence should be admitted:

I. Is there a generally accepted theory in the scientific community which supports the conclusion that DNA forensic testing can produce reliable results?
II. Are there techniques or experiments that currently exist that are capable of producing reliable results in DNA identification, and which are generally accepted in the scientific community?
III. Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case? (People v. Castro, 1989).

On August 14, 1989, the New York Supreme Court held that "DNA identification theory (prong-1) and practice (prong-2) are generally accepted in the scientific community, DNA forensic identification techniques and experiments are not novel, and DNA forensic identification evidence meets the Frye standard," (People v. Castro, 1989). However, the court ruled that in this case the third prong was not met since Lifecodes did not use

generally accepted scientific techniques for obtaining their results, so the DNA evidence was ruled inadmissible. Judge Sheindlin also recommended extensive discovery guidelines for DNA pretrial hearings in the future. Castro's case was never tried; he confessed to the murders in late 1989.

The Castro 3 prong test serves as a stardard for which future DNA evidence can be judged in pre-trial hearings. The case highlited the need for rigorous experimental standards for performing DNA fingerprinting, including proper positive and negative controls, so the FBI created its "Technical Working Group on DNA Analysis Methods" or TWGDAM, whose universal recommendations remain in effect to this date (Federal Bureau …1998).

U.S. v. Matthew Sylvester TWO BULLS, 1990

In 1990, the U.S. District Court for the District of South Dakota sentenced Matthew Two Bulls to prison for aggravated sexual abuse and sexual abuse of a minor. The charges arose from the rape of a teenage girl on the Pine Ridge Indian Reservation in South Dakota. The girl's underwear had been recovered, and the FBI used DNA profiling to determine there was a very high probability that the semen on the underwear came from Two Bulls (U.S. v. Two Bulls, 1990). The defense argued to have the DNA evidence made unavailable, however, the district judge determined the DNA evidence admissible after hearing only one testimony supporting the scientific community's acceptance of DNA evidence. Two Bulls appealed.

During the appeal with the U.S. Court of Appeals 8th Circuit, his sentence was postponed and he was released on bond. Two Bulls argued that the standard in which the

trial court applied when determining the admissibility of the DNA evidence should have used the more rigorous Frye standard, not Rule 702 (U.S. v. Two Bulls, 1990). In addition to deciding whether the scientific community generally accepts DNA evidence, Two Bulls also argued (like Castro) that the testing's reliability and performance should also have been questioned. The appelate court ruled the district court had made a mistake allowing the DNA evidence without questioning the Frye standard, and specific test performance. A new pretrial hearing was to determine the admissibility of the DNA evidence by applying the standards of Frye, Rule 702, Castro, and two additional standards added by the Court of Appeals to make a new *5-prong test*:

I. Whether DNA evidence is generally accepted by the scientific community?
II. Whether the testing procedures used in this case are generally accepted as reliable if performed properly?
III. Whether the test was performed properly in this case?
IV. Whether the evidence is more prejudicial than probative in this case?
V. Whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under Rule 403 (United States v. Two Bulls, 1990)?

After lengthy deliberation, on October 31, 1990, the appelate court ruled the DNA evidence admissible, and upheld Two Bulls original conviction of aggravated sexual assault and sexual assault of a minor.

This case illustrates the general acceptance by 1990 of the underlying theory of DNA testing, and its new role at the national level. As with People v. Castro, this case cautions future cases not to be too accepting of DNA testing unless it is performed properly.

PEOPLE of the State of Illinois v. Reggie E. MILES, 1991

In 1991, Reggie Miles was convicted by the State of Illinois 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 (People v. Miles, 1991). The evidence included regular fingerprints and semen stains, whose DNA was found to match Miles by scientists at Cellmark Diagnostics, a DNA identification company in Maryland who followed the then newly established TWIGDAM guidelines publicized by the FBI.

Miles appealed the convictions in the Appellate Court of Illinois, Fourth District, arguing the State did not provide evidence that the techniques used by Cellmark produced reliable results. However, after validating all the DNA results, on August 6, 1991, the appellate court denied his appeal, upholding the earlier State's conviction. This case ended with a general strong support for DNA evidence, and faith that the techniques recommended by TWGDAM can produce reliable results. After years of considering the admissibility of DNA evidence, in the Illinois case of the People v. Miles, most of the brutal questioning finally came to a stop.

Daubert v. Merrell Dow Pharmaceuticals, 1989, 1991, 1993

Daubert v. Merrell Dow Pharmaceutical was a landmark case that questioned whether the Frye general acceptance test for admitting scientific expert testimony had been superseded by Rule 702 of the Federal Rules of Evidence (Daubert v Merrell Dow, 1989; 1991; 1993). The parents of Jason Daubert and Eric Schuller sued Merrell Dow

Pharmaceuticals, Inc., arguing Dow's drug Bendectin, taken by the children's mothers to control nausea during pregnancy, caused the babies' birth defects. Merrell Dow moved the suit from the state of California to the federal district court. As expected, Merrell Dow provided experts testifying "that none of the more than thirty published studies, involving more than one hundred and thirty thousand patients, showed any evidence that Bendectin caused birth defects, and that none of the studies had found Bendectin to be capable of causing malformations in fetuses,"(Daubert v Merrell Dow, 1993). The plaintiff's responded with the testimony of experts who relied on animal studies and a re-examination of the published studies to prove that Bendectin did indeed cause birth defects. However, the judge dismissed the plaintiff's claims on the basis that the scientific theories of the experts failed to meet the Frye general acceptance standard. The district court stated that scientific evidence is admissible only if the principle upon which it is based is "sufficiently established to have general acceptance in the field to which it belongs," (Daubert v Merrell Dow, 1993).

The plantiff's appealed to the U.S. Court of Appeals for the Ninth Circuit, who affirmed the district trial court's ruling, it went on to declare that the experts' opinion was based on a methodology that diverged "significantly from the procedures accepted by recognized authorities in the field… and cannot be shown to be *generally accepted* [i.e. Frye test] as a reliable technique" (Daubert v Merrell Dow, 1991).

The plaintiffs appealed to the U.S. Supreme court, arguing that when the Federal Rules of Evidence were revised, those rules abandoned the Frye test. The U.S. Supreme Court agreed, finding that the Rules of Evidence were proposed to *expand* the range of admissible evidence, assigning to the trial judge the task of ensuring that an expert's

testimony both rests on a reliable foundation and is relevant to the task at hand. The decision is now known as the *Daubert Standard of Evidence Admissibility* (Daubert v Merrell Dow, 1993). After analyzing the details of the Frye standard and the Federal Rules of Evidence, the Court put forth 5 criteria to characterize the weight of evidence:

I. Whether the theory or technique has been tested?
II. Whether the theory or technique has been subjected to peer review and publication?
III. Whether the theory or technique has a known or potential rate of error.
IV. Whether the theory or technique has standards for controlling the technique's operation.
V. The degree to which the theory or technique has been accepted in the relevant scientific community (Daubert v Merrell Dow, 1993).

Since 1993, these new Daubert criteria, based on an expansion of Rule 702, have been used as the fundamental basis for admitting scientific expert testimony. Upon applying these criteria, the trial judge will determine whether the expert will be testifying "to scientific knowledge that will assist the trier fact to understand or determine a fact in issue," (Daubert v Merrell Dow, 1993).

The Supreme Court reversed the appellate court's exclusion of evidence, and sent the case back to the Appellate Circuit court to be reconsidered. Applying the Daubert standards established by the Supreme Court ruling, the Circuit court reevaluated trial court's exclusion on the plaintiff's proffered testimony. The Circuit court found that the trial court's reasoning under the Frye standard also included sufficient justification to exclude the evidence under the new Daubert test, so the Circuit court then reinstated the trial courts exclusion of the evidence (Daubert v Merrell Dow, 1993).

This Daubert case finally established that the Federal Rules of Evidence (and Rule 702) supercede Frye, and put to death the singular use of the Frye

standard for evidence inclusion (Lyons, 1997; Green et al, 1999; Blackmun, 2004). The Daubert standard has been applied to DNA evidence in post 1993 cases.

CHAPTER-4: DNA DATABASES

Now that we have discussed what DNA fingerprinting is, and some of the court cases involving DNA, we are ready to move to one of the most controversial topics in DNA fingerprinting, the topic of DNA databases. A DNA database is a collection of DNA profiles on a computer used to compare a single DNA fingerprint against a large number of DNA samples. This chapter will discuss the background, methods, uses, and problems associated with DNA databases. We will also examine a case study involving DNA fingerprinting and the controversial ethical issues that lie within.

CODIS, The World's Largest DNA Database

The FBI laboratory's Combined DNA Index System (CODIS) is the U.S. National DNA database that connects federal, state, and local law enforcement agencies. CODIS began in 1990 as a pilot program serving 14 state and local laboratories ("CODIS – National DNA Index System", 2004), and it became national in 1994 when the DNA Identification ACT was passed (Inspector General, 2001). It did not begin national operation until 1998. There are two indexes in CODIS, the Forensic Index which contains DNA profiles from crime scene evidence, and the Offender Index which contains DNA profiles of individuals convicted of violent crimes and sex offenses ("CODIS – National DNA Index System", 2004). A single DNA fingerprint or profile is taken at the local level and then the local laboratory passes the profile to the state level laboratory and then finally to the federal laboratory. This method of originating at the local level and moving

to the federal level allows each individual lab to operate in accordance with their respective local laws. Currently, forensic scientists in the U.S. analyze 13 core loci which have been carefully selected over the years to provide reliable data, with excellent probabilities. This is the information entered into the database. The core loci contain no known medical information, but instead analyze highly unique sites in the junk regions between genes. Currently whose DNA gets collected varies from state to state. For example, Massachusetts in 1997 approved legislation requiring all convicted felons to submit their DNA to CODIS, however in 1998 an appeal by the ACLU (American Civil Liberties Union) was passed in a Boston court stating it was a clear violation of human rights (Jacot, 2000). Virginia law authorizes the taking of a DNA sample from people accused of a violent crime upon their arrest, and a number of officials around the U.S. have proposed taking DNA from people arrested for any crime serious enough to require processing at a station house (Lee and Tirnady, 2003). Louisiana law authorizes the inclusion of DNA profiles in its databank for all people merely arrested for a felony sex offense, and some states have included categories of misdemeanors under their DNA registry laws (Lee and Tirnady, 2003).

Probabilities of a Match

The usefulness and accuracy of the database grows proportionally to the number of profiles stored. Databases are used to determine specific allele frequencies at forensic loci. For example, locus-A might be determined to have a frequency of 0.1, and locus-B a frequency of 0.2 in a database population. If both loci are analyzed for a given DNA sample, the probability of a similar match occurring randomly would be 0.1 x 0.2 or 0.02,

so we would “expect” about 2% of the general population to have a similar profile. Frequencies determined from a database of a million entries are far more accurate than those determined from only 100 entries. Thus CODIS with its 1,857,093 current profiles (“CODIS – National DNA Index System”, 2004) has allowed the assignment of specific allele frequencies far more accurately than in the past. When using the 13 CODIS core loci, one can typically achieve a frequency on the order of one-in-a-billion to one-in-a-trillion that the profiles will match random, non-related subjects (Luftig and Richey, 2001). It is important to remember that DNA exclusion can be determined with almost certainty, while DNA inclusion can not. So for example, if a semen sample from a rape victim does not match a suspect, that evidence alone is often sufficient to exonerate them. While trying to prove guilt is more demanding, requiring not only the analysis of many loci, but the analysis must be properly done on un-contaminated samples.

Database Ethics

Some people are against the creation of a national database. The formation and use of databases sounds practical for helping to solve crimes, however there are looming concerns about such personal information. DNA sequences can contain very intimate information about the individual, and privacy of this information is a foremost concern. ACLU’s associate director Barry Steinhardt discusses a survey conducted by the American Management Association which found that six percent of employers are already using genetic tests as a part of hiring practices (Jacot, 2000). "While DNA databases may be useful to identify criminals, I am skeptical that we will ward off the temptation to expand their use," said Steinhardt. "In the last ten years alone we have gone

from collecting DNA only from convicted sex offenders to now including people who have been arrested but never convicted of a crime (DNA Databases Hold More…, 2000). A person's DNA contains important information on parentage, physical traits, medical history, behavioral propensities, susceptibilities to mental illness, and arguably even one's basic intelligence. If such information was included in a DNA database, allowing other people access to such intimate information could open a Pandora's Box and release a host of new problems through genetic discrimination. This knowledge could potentially affect hiring in the workplace, or even insurance coverage and premiums. For example, if your DNA profile was taken before you were to purchase medical insurance, and it was determined that you may have a genetic predisposition to cancer, although there is no guarantee you will actually be diagnosed with cancer, this gives an insurance company the ability to charge you triple what your neighbor has to pay for the same coverage. If we take this one step further a government could use the information to wipe out a mass of people in order to prevent the transmission of a genetic disorder. Let's look at being framed as another example. As your DNA is sitting in a lab somewhere, who is preventing a lab technician or a crooked police officer, or whoever has access to your DNA from planting it at a crime scene to frame you for a crime you did not commit. However, what the public is not aware of is that the currently used 13 core loci were chosen in part because they contain no known medical information. This fact, coupled with a mandated requirement to destroy the original DNA sample so no known medical locus could be subsequently analyzed, would negate much of the public's objections with DNA databases.

This may be very unlikely, however not out of the realm of possibility. More likely is the misinterpretation of the bands on DNA fingerprinting which has been an issue in court since the inception of the practice. The scientific theory associated with creating the fingerprint seems almost foolproof, but standard procedures need to be implemented to ensure the theory is correctly practiced. In fact, this was recently done with the recommendations of the "technical working group on DNA methodology" or TWGDAM. As you can see, privacy is a major issue when dealing with high profile confidential information. People need to be aware that the 13 loci used in CODIS have no medical information in them. Therefore this idea of medical information being used against an individual is thrown out the window.

Another major issue concerning databases is the collection of profiles. Currently in most states, the profiles are limited to individuals involved in violent crime, paternity testing, and immigration. Look at the current statistics; in about 60 percent of cases where DNA is found at a crime scene there is no match in the database, therefore the offender is someone without a previous record (The Welcome Trust, 2004). Most people are not willing to go to their local police stations to submit a DNA sample especially without knowledge of who has access to the sample or where the sample is going. Law prevents involuntary sampling of those persons not involved in violent crimes or sex crimes. How useful is a database if it does not consist of a random sampling of individuals? Legislation could be passed to mandate a sample of DNA be submitted by every citizen. Professor Jeffreys himself states, "The answer is simple – expand the current database to include everyone, it gets around the discrimination problem: if we're all on the database, no one is being discriminated against….but this global database

should not be held by the police, as that would send out all the wrong signals (The Welcome Trust, 2004)." However, after you are mandated to give your sample where does the violation of human rights end?

Example of Using a "DNA Database" to Solve a Crime

The first case in which a person was convicted for murder using DNA evidence gives the basis of DNA fingerprinting used in criminal investigation today. On November 22, 1983 Lynda Mann 15 was found murdered only a few miles away from her home in England. It was not immediately evident who had committed the crime. The police were unable to come up with any leads to catch the offender, but he had left a bit of evidence behind. The killer rapist had left a small sample of his semen. Four years later on July 31, 1987 Dawn Ashcroft, also 15 years old was raped and strangled to death. Based on the modus operandi, the police believed that the same man had committed both crimes. The police began a massive man hunt and the only lead was a local dishwasher. At first he denied any association with the crime but after extensive questioning he admitted to the first murder, although his testimony was incoherent and often contradictory. The police decided to use DNA fingerprinting for the first time in a criminal investigation. After the results came in, the police were surprised to see that the DNA testing proved that the dishwasher was innocent of both murders.

A massive DNA profiling of every male in the township who did not have a strong alibi began. Months passed and hundreds of DNA profiles were taken from blood samples and given to the neighborhood police, in effect making the world's first "DNA database", but none of them matched the semen found on the bodies of the two girls.

Then the big break came. A young woman who managed a local bakery mentioned she had overheard a man confessing to another that he had paid someone to go in his place to give blood in his name. The man was named Colin Pitchfork. Pitchfork had a previous criminal record and had been arrested several times for indecent exposure. The police confronted Colin Pitchfork with the murder accusations, and being convinced that the DNA identification would show up positive, Pitchfork admitted to both crimes. A DNA sample was taken from Colin Pitchfork and it was a match. He was guilty of the rape and murder of both girls (NIFS, 2001)."

After examining this case study one can quickly identify the practicality and controversy of DNA fingerprinting. In this case study, the dishwasher admitted to a crime he did not commit, and if DNA fingerprinting had not been employed he would have been convicted of said crime. This mass profiling was in fact creating a database to compare the DNA evidence found at the crime scene. You can also see the controversy in the involuntary mass profiling that followed the dishwasher's declaration of innocence. Ask yourself why should you be considered a suspect on the sole fact you live in the vicinity of a crime scene? Do you have the right to refuse submitting a sample of your DNA to police? Do not forget the man who was paid to submit a sample for another man. This raises the question of how can you be sure the sample the police use to convict or free someone truly belongs to that individual?

Database Conclusions

As one delves further into the nuances of this topic you begin to see two arguments. The first, those who support DNA databases, understand the usefulness that

comes from being able to convict criminals with a solid piece of irrefutable evidence. After all, a criminal can alter his or her normal fingerprints using a file, but can not alter their DNA profile left at a crime scene!! The second, those against DNA databases, namely individuals who fear government control of highly confidential, potentially disastrous information, fear the inaccurate subjective nature of interpretation can have ugly consequences. As sociologist Gary Marx has put it, observing from his position at the Massachusetts Institute of Technology, "One risk is that the DNA technologies work and the other is that they don't." At the one extreme – if they work – they might provide too much information and become an invasion of privacy. At the other extreme – if they don't work – innocent people might suffer (Lampton, 1991). I personally side with the supporters as I am not one to believe highly in government conspiracy and the notion Uncle Sam is looking to frame us for crimes we didn't commit. I believe that Professor Jeffreys is correct is stating if everyone is on the database then discrimination is tossed out the window. As I am a supporter of a national DNA database, I also realize the sensitivity of DNA information being stored and used at the governments will, thus I agree with the recent trend towards using only well known forensic loci not known to contain any medical information in all database entries, and am in favor of legislation mandating destruction of the DNA sample once a forensic profile has been obtained. I am not so reluctant to question the accuracy and validity of the tests as educated, trained individuals must have our trust if they are able to complete their jobs successfully. Much like a doctor has our trust when prescribing medicines or diagnosing disease. So I am in favor of the TWGDAM standards for DNA evidence collection, storage, and analysis.

If we as a society can agree on who regulates and controls database information I believe the pros far outweigh the cons, meaning an individual's right to privacy (i.e. to not give a blood sample) is forfeited when that person is convicted of a felony crime. One solution to keep anonymity in a database designed to collect "random" samples, not criminal samples, could be to submit a sample of your DNA, then have any record of the sample belonging to an individual be destroyed such that the sample can only be identified by a number. This way a lab tech or individual handling the sample would have no way of knowing which person's DNA they are handling, yet the database could be enormous in size, making the assignment of allele frequencies far more accurate than those obtained using criminal databases. For criminal databases, the only way to connect samples to individuals would be to access the files on the database and access to the database would be extremely limited, certainly not including insurance companies or prospective employers.

CHAPTER-5: CONCLUSIONS

This IQP project was an effort to bring a greater understanding of DNA fingerprinting and its uses to the authors, and especially to use this subject as an example of how a technology can have a strong impact on society. The project began with an examination of DNA structure, various techniques used to create DNA profiles, and a discussion of the proper methods for collecting and preserving DNA forensic evidence. Those topics were followed by a discussion of landmark DNA court cases that set U.S. legal precedence for allowing technical evidence (including DNA) in the courtroom. Finally, the controversial topic of DNA databases was explored focusing on their uses and ethics.

Although each person's DNA sequence is unique, a person's entire genome is not analyzed in a DNA fingerprint. Instead, current forensic analyses focus on highly variable locations (loci) on the DNA molecule that are most likely to be different between individuals. The loci analyzed contain short sequences repeated a variable number of times between individuals, so they are called "variable number of tandem repeats" (VNTRs). An RFLP (or Southern) type of fingerprint is used to analyze VNTRs several hundred base pairs long, while a PCR analysis is usually used to analyze short tandem repeats (STRs) that are only about one hundred base pairs long. Over the years, forensic scientists have identified new STR loci that can be added to a DNA analysis, greatly helping to the accuracy of a match. The currently approved standardized procedure used by the FBI uses 13 core loci.

The ups and downs of the OJ Simpson murder trial ("The Trial of the Century") taught us the need to carefully document "chain of custody" in evidence handling, and to use procedures that prevent contamination and DNA degradation. Heat and moisture can cause severe degradation to samples, so DNA evidence should not be packaged in plastic containers because plastic does not allow moisture to escape. Because PCR analysis is so sensitive, it can amplify small amounts of contaminating DNA, so it is essential that only clean instruments be used in sample collection, and control samples should be taken representing portions of fabric not containing biological fluids. The more informed law enforcement personnel are about possible contamination and proper packaging of forensic evidence, the more likely crime scene personnel will know how to handle it.

The acceptance of technical evidence in U.S. courts was not a straightforward process. Several landmark court cases were described in this IQP that set legal precedence for admitting such evidence. These cases included Frye v U.S. (1923) that set a standard for *general acceptance* of a technique in the scientific community before it can be admitted, Federal Rules of Evidence (Rule 702) (1975) that softened the difficult to achieve Frye standard by allowing expert testimony to address the *reliability* of the technology, Downing v U.S. (1985) that concluded evidence *relevancy* should be the main basis of admissibility, People v Castro (1989) that very critically evaluated DNA technology up to that point in time and established a three prong test for allowing DNA evidence in the courtroom, and Two Bulls v U.S. (1990) that expanded the 3-prong Castro test into a 5-prong test.

The final subject of this IQP was the controversial topic of DNA databases. The world's largest DNA database is the FBI's Combined Index System (CODIS) system,

representing a linked local, state, and national system. A major conclusion of this IQP is that an expanded use of CODIS is critical to solving future U.S. court cases. The database includes DNA profiles from crime scenes, as well as profiles from *convicted* U.S. felons. When fresh evidence is gathered from a crime scene, its profile is compared to entries in the database. A match to a previous offender helps catch repeat offenders, while a match to another crime scene helps establish links to other crimes. Although such databases provide enormous aid in solving crimes, ethical issues surround the topic of *who's* DNA should be included in the database. Currently, such decisions are decided at the level of state government. We agree with the current Massachusetts legislation requiring all persons *convicted* of felonies (and certain types of misdemeanor sex crimes) to submit samples to CODIS, and disagree with states that only require donation from *violent felons*. One author of this IQP report wants the required DNA donations to be extended to include all individuals *suspected* of committing a crime, in agreement with other items taken from suspects such as normal fingerprints. We disagree with arguments that all U.S. citizens should be required to donate a sample, since that would violate privacy rights, but feel such rights are forfeited by persons convicted of committing a crime at the time the crime is committed. Based on the research performed for this IQP, we disagree with public fears that medical information is contained in CODIS, but agree that the original DNA sample should be destroyed to prevent future DNA information (including medical predispositions) from being entered into any database.

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