03B0031

IQP-52-DSA-6526
IQP-52-DSA-3947
IQP-52-DSA-4364

DNA FINGERPRINTING

An Interactive Qualifying Project Report:

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

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Date: October 27, 2003

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ABSTRACT

DNA fingerprinting is a growing technology which is greatly changing law enforcement. The purpose of this project was to investigate this new technology, and to determine its impact on society by analyzing court cases and the ethics of DNA databases. Chapter one presents background information about DNA profiling and fingerprints, chapter two presents methodology on collecting DNA samples. Chapters three and four give information about landmark and sensational court cases, respectively. Chapter five discusses the use and ethics of DNA databases. Chapter six, describes the report conclusion.

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EXECUTIVE SUMMARY

The scientific technique of DNA fingerprinting, which analyses the uniqueness of people's DNA, was invented by Alex Jefferies in the mid-1980's as an extension of the "Southern blot" procedure for analyzing specific DNA fragments. Since its invention, this technology has had an amazing impact on society, especially the field of criminal forensics where arguably it has been called the greatest forensic tool in the history of forensic science. Almost all cells in an individual contain DNA, and the DNA in each cell of an individual is identical to his other cells. Thus if a small portion of tissue (like saliva, blood, semen, hair, etc) is left behind at a crime scene, its DNA can be analyzed to see if it matches the DNA from other cells in a suspect.

Several techniques are used for performing DNA fingerprinting. One of the most useful is "variable number of tandem repeats" (VNTR) analysis. Much of the DNA between individuals is very similar, it is what makes us human. However, some of the DNA is considered "junk" DNA, which codes for no known proteins. This junk DNA varies considerably between individuals, and is the subject of DNA fingerprint analysis. In some of this junk DNA, tandem repeats (like CG) repeat various numbers of times at a specific location (or locus). In VNTR analysis, the DNA is cut, separated by size, blotted to a membrane, then hybridized to a probe specific for one VNTR locus. The length of the observed fragment is specified by the number of repeats at that locus. So VNTR analysis essentially analyzes the length of these fragments to compare to other individuals. A second technique frequently used in forensics is polymerase chain reaction (PCR) which is a technique used to amplify DNA. This technique is so sensitive it allows the analysis of DNA when only a few cells are left behind at a crime scene. A

third and most frequently used technique which combines the first two techniques is short tandem repeat (STR) analysis. STR's are like VNTR's (containing different numbers of repeat sequences) but are much shorter than the average VNTR. Thus STR's can easily be amplified by PCR, the lengths of the fragments are very easy to determine, and require no radioactivity unlike VNTR analysis.

Although DNA fingerprinting is an amazing forensic tool, its acceptance in the courtroom has not been straightforward. In many court cases, DNA evidence was not allowed because it did not meet accepted standards for allowing technical information in U.S. courts. In a series of landmark court cases, slowly the criterion was laid out for accepting DNA evidence. These criterion include the acknowledgement that DNA testing has gained general acceptance in the scientific community, that standards have been established for how to perform such testing, and that such standards were followed in a specific court case.

While the landmark court cases define the criterion for accepting DNA evidence in court, the public is really only aware of DNA testing through sensational cases. These cases are trials of famous people, like the Boston Strangler (where recent evidence indicates that convicted perpetrator Albert Desalvo's DNA was not present in last victim Mary Sullivan), and OJ Simpson (where we learned about the need for stricter DNA contamination control). These famous cases may not have set any legal precedents for DNA evidence, but provide the public with examples of its use.

In order to establish the probability of a match between two DNA samples, the frequency of a particular allele (gene type) in the general population needs to be known. For example, if we analyze locus X and determine the crimescene DNA has 32 repeats at

this locus which matches the 32 repeats seen in the suspect, then what is the likelihood of a random DNA sample having 32 repeats at this locus? To determine this, DNA databases have been established. Such databases record the DNA analysis of a variety of DNA samples, and allow extrapolations of frequencies observed there to the general population. Initially when the databases were small, the extrapolations were often critisized by defense lawyers as being too inaccurate. This resulted in the DNA evidence from a number of early cases being thrown out.

Since then, laws in several states have mandatated that convicted felons provide blood for DNA testing. This drastically increased the size of DNA databases, and increased the accuracy of probability determinations. This criminal database is known as CODIS, is maintained by the FBI, and is the world's largest DNA database. The database not only drastically improved probability determinations, it also has been enormously useful for finding repeat offenders (i.e. when DNA left at a new crime scene matches a previous offender in the database who has been released from jail) and for finding links between related cases performed by one perpetrator.

The public is often against establishing DNA databases, claiming it violates 4th amendment rights to privacy. However, convicted felons don't have 4th amendment rights, so CODIS remains legal. However if larger databases from the public are eventually required to assign even more accurate probability accessments, considerable public opposition can be expected since they will worry about their medical predisopsitions falling into the wrong hands. Based on the research performed in this IQP, the authors feel this opposition is ungrounded since the type of information entered into such databases on VNTR and STR lengths, represents junk DNA with little to no

medical information. So long as legislation mandates the destruction of the original sample after forensic non-medical analysis, then no means exists for extrapolating medical information.

CHAPTER 1: WHAT IS DNA PROFILING, AND HOW ARE DNA "FINGERPRINTS" MADE?

DNA

Throughout history, the human race has strived to reduce the amount of materials needed to accomplish goals. Increased motor efficiency has allowed for the construction of cars that use a minimum amount of fuel. Computers have been built that can fit in the palm of a person's hand. Nothing, however, has been reduced in size more than the amount of material needed to determine the difference between two people. This difference can be determined using something as small as a drop of blood.

With the exception of red blood cells, all of the cells in the body contain a nucleus. It is inside this nucleus that the molecule which encodes genetic information, deoxyribonucleic acid or DNA, is found. DNA is the chemical structure which forms chromosomes. Chromosomes are usually found in pairs, and all humans have 23 chromosomes from each parent. A gene is a section of the chromosome which is

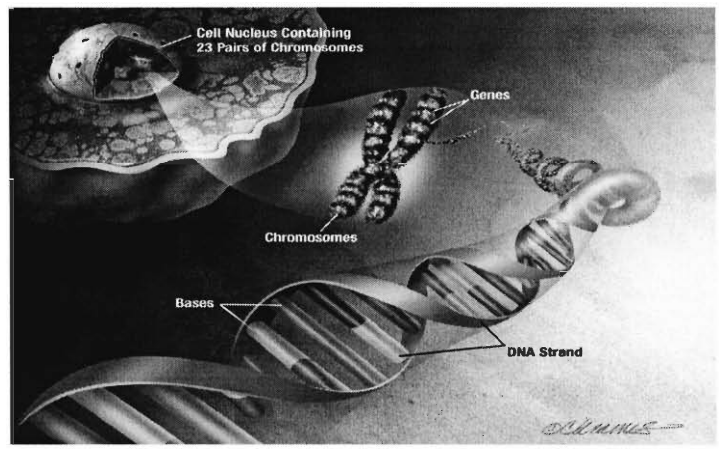

Figure 1 DNA, Chromosomes, and Genes
(http://www.alzheimers.org/rmedia/graphicshighres.htm)

responsible for a particular trait. Structurally, DNA is shaped like a long double helix, as can be seen in the following figure. The backbone is made up of repeated sequences of phosphate and deoxyribose sugars. Four different organic bases attach to the sugars. These bases are: Adenine (A), Guanine (G), Cytosine (C), and Thymine (T). Because of their chemical structures, only certain bases are able to pair together. Adenine always bonds with Thymine, and Cytosine always bonds with Guanine. Thus the four combinations that can occur, and which form the staircase are, T-A, A-T, G-C, and C-G. The following figure shows how the phosphates and sugars are arranged in the backbone, and how the base pairs are arranged.

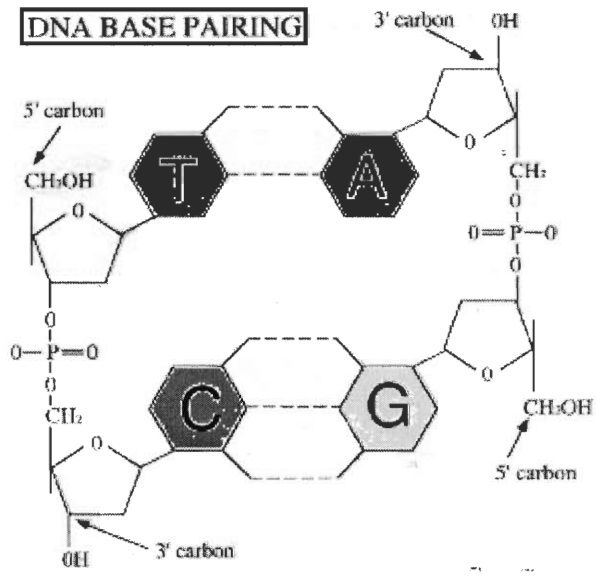

Figure 2 DNA Base Pairs & Phosphate - Sugar Backbone (Brinton and Lieberman, 1994)

"Suppose one strand of DNA looks like this:

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

The DNA strand bound to it will look like this:

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

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

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

DNA strands are read in a particular direction, from the top (called the 5' or "five prime" end) to the bottom (called the 3' or "three prime" end). In a double helix, the strands go opposite ways: (Brinton and Lieberman, 1994)"

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

Each DNA molecule has about three billion base pairs. These pairs are arranged in specific sequences or orders. Different sequences are responsible for the creation of different parts of the body. DNA base pairs are arranged differently among people. Variations between people are called polymorphisms. Polymorphisms are found in the 95% of DNA that does not encode any proteins (i.e. is the non-coding region). In some segments of DNA, short, identical repeat sequences that can repeat one to thirty times in a row called variable number tandem repeats, or VNTRs. A DNA fragment's length is determined by the number of copies of a VNTR, and the number of VNTRs on a chromosome varies between individuals (Hartwell et. al, 2000).

Fingerprinting

During the early 1980s, British scientist Alec Jefferys used DNA typing or DNA profiling (now known as DNA fingerprinting) to release a suspect who had been falsely accused of murder. Jefferys analysis of DNA samples allowed officials to determine that

the man arrested was not the man who committed the crime. The theory behind Jefferys work was that no two people have the exact same DNA sequence (Bagshaw, 2002).

The chemical structure of DNA does not vary from person to person. Only the sequence, and number of repeats, is different among people. In theory, every person could be identified by their DNA sequence. Because of the large number of base pairs in each DNA molecule, however, it would be extremely time-consuming use complete DNA sequences for identification. Instead, scientists have used the repeating patterns of DNA to create a short-cut identification method. A small carefully chosen portion of the DNA can be analyzed to determine the probability of a match between two samples of DNA. Although these repeating patterns do not provide actual individual "fingerprints", they do allow scientists to determine whether two DNA samples came from the same person, related people, or non-related people (Brinton and Lieberman, 1994).

DNA Fingerprinting: The Process

The existence of restriction fragment length polymorphisms, or RFLPs, is the basis for DNA fingerprinting. Single base changes can create or delete a restriction site in the DNA, and probes can be used to detect changes in restriction patterns. The process of DNA fingerprinting involves numerous steps. First a polymerase chain reaction, PCR, is performed to generate enough DNA for testing. A southern blot analysis is then performed. The first step in a southern blot analysis is to digest the sample DNA with restriction enzymes to break it into fragments. The DNA is then separated on an agarose gel and transferred to a nylon membrane. The membrane is incubated with a probe, and a detection method is used to see where the probe bound to the DNA.

The following figure shows the southern blot procedure.

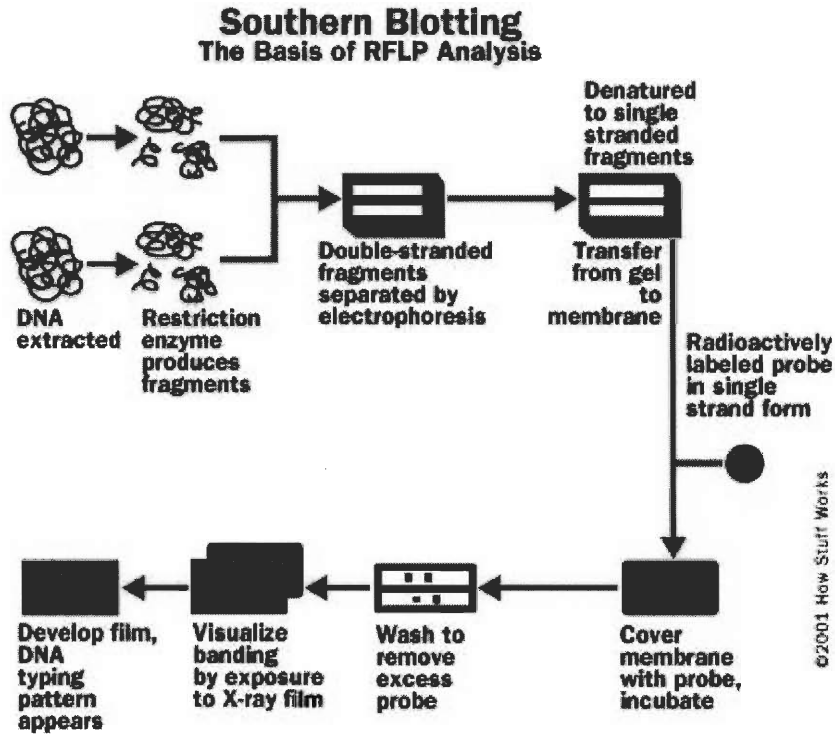

Figure 3 Southern Blotting (How Stuff Works, 2001)

PCR

PCR is an amplification method for small segments of DNA. If there is not enough DNA present to perform a southern blot analysis, a PCR reaction will be done prior to the southern blot. In order to run a PCR reaction, two primers are needed that will bind on each end of the DNA template to be synthesized. A thermocycler is used for PCR. The DNA is denatured, or split into single strands, by heating it in the thermocycler. The temperature is then lowered so that the primers can anneal to the DNA. The temperature is then raised so that the DNA can be synthesized in the 5' to 3' direction. This procedure is then repeated about thirty times. After the first round, the new strands of DNA serve as templates for subsequent rounds. With each round of

synthesis the number of fragments doubles, and the amount of DNA increases exponentially. After thirty rounds, enough DNA is present to be detected by gel electrophoresis and staining (Bagshaw, 2002).

Restriction Digestion

Restriction enzymes protect bacterial cells by destroying foreign DNA. These enzymes recognized specific sequences of bases, usually four to eight bases, and cut the DNA at or near that sequence. The result of a restriction digestion is DNA that has been cut into pieces. Common restriction enzymes used include TaqI, Sau3A1, EcoRI, BamHI and HindIII. EcoRI recognizes the sequence GAATTC and cuts between the G and A. HindIII recognizes the sequence AAGCTT and cuts between the As. BamHI recognizes the sequence GGATCC and cuts between the Ts. TaqI cuts between the T and C in the sequence TCGA, and Sau3A1 cuts before the G in the sequence GATC (Bagshaw, 2002).

Agarose Gel Electrophoresis

The resultant DNA fragments are then placed in the wells of an agarose gel. The gel is put in a buffer solution with electrodes on either end. The negative electrode is placed on the end with the DNA, and the positive electrode is placed on the end of the gel opposite the DNA. A current is then created between the two electrodes. The negatively charged DNA migrates towards the positive charge. The DNA fragments are separated by size because the smaller fragments can move more quickly and easily through the pores of the agarose gel. A DNA marker is usually put in one of the wells so that the size of the fragments can be determined if necessary. The gel is then placed in ethidium

bromide, which binds to the DNA. When the gel is placed on an ultraviolet light box, the ethidium bromide fluoresces orange and the DNA fragments can be seen (Bagshaw, 2002). The following figure shows a sample gel with a marker in the far left lane.

Figure 4 Results of an agarose gel electrophoresis (http://www.ucalgary.ca/md/BTC/agarosegel.html)

After the gel has been run, the DNA has to be denatured. The denaturation is done by heating or chemically treating the DNA while it is still in the gel. A nylon membrane is then placed under the gel, and filter paper that has been saturated with transfer solution is placed on top of the gel. The downward flow of transfer solution deposits the DNA fragments on the membrane exactly as there were in the gel, thus the restriction pattern is not altered. The southern blot is now completed and ready for analysis (Bagshaw, 2002).

Making the Probes

A probe is a labeled strand of DNA that is used to find specific sequences in a southern blot. ^{32}P and ^{35}S are commonly used to make radioactive probes. One method

for making a probe is the nick translation method. The DNA to be used is nicked, or broken along the strand. Once the DNA is nicked, individual nucleotides are added to the DNA. One of the nucleotides will have ^{32}P or ^{35}S, which will make it radioactive. DNA Polymerase is the added to repair the nicks in the DNA. Hydrogen bonds are formed between the nucleotides on the broken pieces of DNA. DNA Polymerase works immediately and moves from the 5'end to the 3' end of the DNA strand. The DNA is then denatured, resulting in one labeled radioactive strand, and one non-radioactive strand. The radioactive strand is the probe (Brinton and Lieberman, 1994).

Hybridization

The formation of a stable, double-stranded nucleic acid structure from two single strands that were not originally partners is referred to as hybridization. The hybridization reaction is the process where the probe binds to the DNA on the nylon membrane. The probe only binds to DNA that is complementary to (matches) the sequence of the probe. The membrane and the probe are placed in saline solution and incubated for a given period of time. If the probe finds a complementary sequence on the DNA in the membrane, it will bind to the DNA. The probe does not have to find an exact fit in order to bind. The amount of binding that occurs if there is not an exact match depends on the reaction temperature and the amount of saline in the mixture. An X-ray is then taken of the nylon membrane. Only areas where the probe bound to the DNA will appear on the X-ray film. The resultant pattern is called a DNA fingerprint (Bagshaw, 2002).

Alternative Detection

Use of a radioactive probe and X-ray film is the not only method of detection. Non-radioactive probes can also be used for Southern blot analysis. Biotin can be linked to the nucleotides instead of a radioactive element. The nylon membrane is the reacted with a complex containing streptavidin which is covalently linked to alkaline phosphatase. A chemiluminescent reaction is then used to detect the alkaline phosphatase. The alkaline phosphatase will dephosphorylate a substrate which undergoes a spontaneous reaction and emits light. Presence of light on the membrane indicates that the probe has bound to the DNA (Bagshaw, 2002).

Applications of DNA Fingerprinting

DNA fingerprinting is commonly used for criminal identification, paternity and maternity testing, and personal identification. In criminal investigations and forensic sciences, tissues such as blood, hair, skin cells and bodily fluids can been used to isolate DNA. The DNA on the evidence is then compared to the DNA of the suspect to see if the VTNR patterns match. Homicide investigators use VTNR patterns to establish identity of victims.

DNA fingerprinting is a valuable tool for paternity and maternity testing because offspring receive chromosomes from both the mother and the father. A DNA sample for the mother or the father should contain sequences common to the DNA of the child. VNTR patterns are so specific that it is possible to reconstruct a parental pattern even if only the child's pattern is known. This type of analysis is commonly used when the father's identity is in question (Brinton and Liberman, 1994). The following figure

shows the results of two paternity tests. The gel on the left indicates that the alleged father is not related to the child because they do not share any common DNA fragments. The gel on the right shows that the alleged father is the child's real father because they share common DNA fragments.

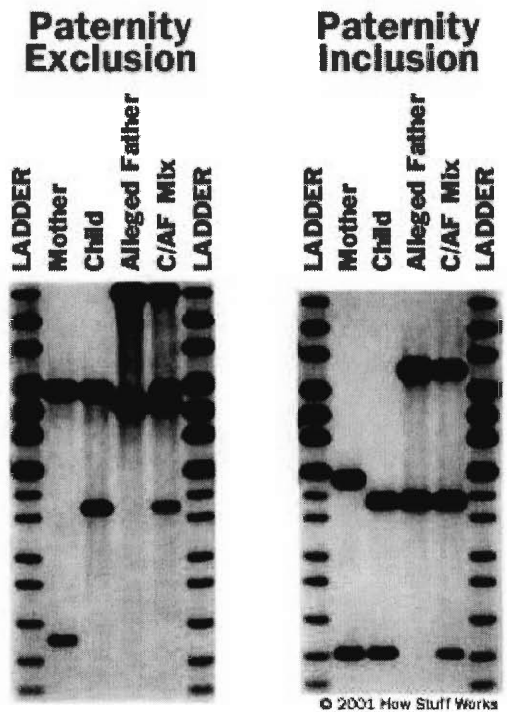

Figure 5 DNA Evidence for Paternity Testing (How Stuff Works, 2001)

Problems with DNA Fingerprinting

Although DNA fingerprinting is a useful tool for many applications, it is not 100% accurate. The name 'fingerprint' is somewhat misleading because single VNTR patterns are not unique to each person. For this reason, 9-11 different VNTR loci are usually analyzed per sample. The probability of identification based on VNTR patterns is usually very high, but based on evidence and the circumstances surrounding each case, the probability can vary. One main issue affecting the validity of DNA fingerprinting is

the quality of work of those involved with the case. Sloppy or careless work, or involvement of a worker who has not been properly trained can greatly influence the accuracy of the results. There is also a chance that two unrelated people have the same fingerprint. The more probes used, the better the odds that no two unrelated DNA samples show the same fingerprint. Rare VNTRs or combinations of VNTRs can also be used to increase the probability of an exact match (Bagshaw, 2002).

CHAPTER 2: FORENSICS

Forensics Introduction

Forensics is the use of science and technology to investigate and establish facts in criminal or civil courts of law. DNA forensics begins at the scene of the crime and, if evidence is correctly collected, can establish a link between a crime and involved individuals. It is the evidence collected using forensic science that is used to incriminate a possible suspect. DNA collected at crime scenes is the most important evidence because it can prove without a doubt who committed the crime. The method of collection, however, can also determine whether the court will allow the evidence to be used during the trial. Carelessness by scene investigators could result in a guilty criminal being allowed to walk free or an innocent person jailed.

Nuclear DNA is found in all cells in the body except red blood cells. At a crime scene, DNA can be found in blood (white blood cells), semen, skin cells, tissue, organs, muscle, brain cells, bone, teeth, hair, saliva, mucus, perspiration, fingernails, urine, feces, and many other places. Due to the skepticism some people have with DNA evidence, standards have been established for its collection. More importantly the investigators need to know where to look for evidence before they can start the tedious process of collecting samples. There are numerous locations at a crime scene where DNA can be found. Forensic scientists have thus developed key locations for finding evidence. Such locations are presented in Table 1.

Table 1 Locations of DNA Evidence (http://www.ncjrs.org/nij/DNAbro/id.html)

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

Crime scene investigators are responsible for collecting and storing evidence. It is the investigator's job to prevent degradation and contamination of the DNA evidence. The investigator must also maintain a strong link in the chain of evidence. The evidence must be collected using sterile materials, and every action involving a sample must be

documented. All crime scene personnel must wear sterile clothing, and use gloves to prevent contamination of the evidence. It is also necessary for a control sample to be included with each different suspect sample. The control sample should be subjected to the same collection methods, but should not be exposed to the suspect sample. A control sample allows the forensics lab to rule out any contamination or corruption.

Prior to packaging any samples, specimens must be allowed to air dry. Small objects should be collected whole and evidence on larger objects should be cut off or swabbed using sterile cotton.

Distilled water and sterile cotton can be used to transfer dried stains. Samples with DNA evidence should be stored in a cool and dry location, so as not to be damaged by moisture or sunlight. Clean paper and or sealed envelopes prevent samples from becoming moist, whereas plastic containers usually expose samples to moisture, and sunlight. If samples are not collected and stored properly they may deteriorate before analysis has been performed. Samples should also be properly labeled and include: time and date, subject's name, location, collector's name, case and evidence identification numbers. Lack of proper documentation may result in dismissal of evidence in the court of law (Kramer, 2002).

Figure 6 DNA sample kit (Courtroom Television, 2003)

Blood Evidence

The most common form of evidence is blood. Blood can be found on a victim, on surfaces, and as stains, and each type of sample requires a certain procedure. Blood found on a victim or surface can either be liquid or dried. Both liquid and dried samples require that the blood is absorbed onto a clean cotton cloth or swab, leaving a portion of the swab unstained as a control. Dried blood, however, requires that the sample be moistened with distilled water before transfer to a swab. The swab must then be air dried and packed in clean paper or an envelope with sealed corners. Blood in snow or water must be collected immediately to prevent dilution and frozen in a clean airtight container. Bloodstains on movable objects are easy to collect because the sample can be wrapped in clean paper. With an immovable object, however, the stain must be cut away from the object and packaged in paper, and then another sample of the clean object must also be collected.

When a sample is submitted to a lab it must be accompanied by a blood examination request letter. The letter requires certain information be known for determining which type of analysis is to be completed. A brief statement of case facts must be provided. It is also important to note the possibility of the blood coming from an animal, or having been diluted with other bodily fluids. Most important is whether there are any health concerns regarding the sample such as AIDS, hepatitis, or tuberculosis.

Semen Stains

Second to blood, semen and semen stains are the next most popular form of evidence left at a crime scene. Liquid semen is to be absorbed onto a clean cotton cloth

or swab leaving part of the swab unstained for control. The swab is then air dried and packed into a clean paper or and envelope with sealed corners. Dried semen-stained objects are to be submitted in clean paper to the Laboratory packed to prevent stain removal by abrasive action or packaging materials during shipping.

Seminal evidence from a victim must be obtained using a standard sexual assault evidence kit to collect vaginal, oral, and anal evidence. The procedure involves collecting the victim's clothing, head and pubic hair combings, vaginal, penile and anal swabs and smears, oral swabs, saliva or blood samples, and fingernail scrapings. The kit is to be refrigerated and submitted to the laboratory as soon as possible.

Saliva or Urine Samples

A clean cotton cloth or swab is used to collect liquid saliva or urine. A portion of the swab is to be left unstained for control. The sample is to be packed in a clean paper or an envelope with sealed corners after air drying. Small dry saliva- or urine-stained objects are to be packed to prevent stain removal by abrasive action or packaging materials during shipping to the laboratory in clean paper. Large stained objects should have a large sample cut with a clean sharp instrument along with a portion of unstained sample for control and packed in paper. Cigarette butts, chewing gum, and envelopes and stamps should all be picked up with clean forceps or gloved hands and placed in a clean paper or an envelope with sealed corners.

Hair Samples

Hair should be collected using sterile forceps to prevent damaging the root tissue. Any hair samples suspected of being mixed with bodily fluids should be air dried before storing. Each piece of hair, or group of hair pieces, should be packaged separately in clean paper, or in an envelope with sealed corners. All hair samples should be refrigerated immediately and submitted to the laboratory as soon as possible for analysis.

Other Tissues, Bones, Teeth

Prior to submitting any samples containing tissues, bones, and teeth, forensic scientists must call the laboratory to ensure that the evidence will be accepted at that laboratory. Following authorization, suspected tissues, bones, and teeth can be collected using gloved hands or sterile forceps. One to two cubic inches of red skeletal muscle is necessary for the sample to be analyzed. For bone, such as the fibula or femur, three to five inches of sample is necessary. Teeth should always be collected in the following order: non-restored molar, non-restored premolar, non-restored canine, non-restored front tooth, restored molar, restored premolar, restored canine, restored front tooth. Tissue samples should be placed in a clean, air-tight, plastic container without formalin or formaldehyde. Teeth and bone samples should be stored in clean paper or an envelope with sealed corners. Evidence should be frozen in Styrofoam containers and shipped overnight on dry ice (Federal Bureau of Investigation, 1999).

Luminol

Sometimes the crime scene gets "cleaned" by the perpetrator before officials are able to investigate. New technology, however, allows the detection of evidence even when no physical evidence seems apparent. Tiny particles of blood will remain on a surface for years. A product called "Luminol" is what scene investigators use on the "clean" scenes. Luminol (C8H7O3N3) powder, a nitrogen, hydrogen, oxygen and carbon compound, is mixed into a hydrogen peroxide, hydroxide and other chemical liquid. The liquid is then sprayed on, for instance, the carpet and a reaction occurs with the blood's hemoglobin and the luminol. The reaction causes a glow when the scene is completely blacked out. This process is known as chemiluminescence.

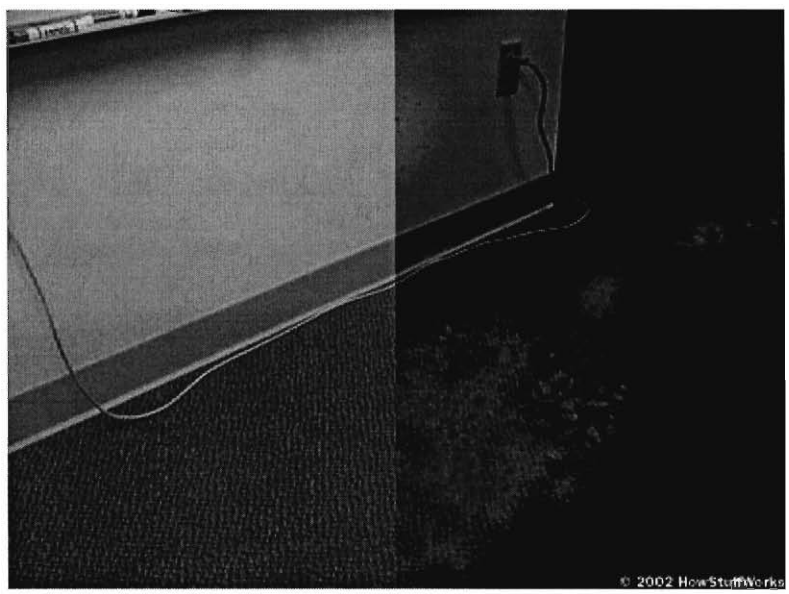

Figure 7 A simulation of luminol at work: Before spraying luminol, there's no sign of blood. After spraying luminol, the latent blood traces emit a blue glow. (How Stuff Works, 2003)

Use of luminol, however, has its disadvantages. Luminol only shows investigators where blood may be located. Other substances, such as household bleach, can react with luminol and cause it to glow. Investigators can make positive

identifications based on the time it takes for the luminol to glow, but additional tests are still necessary to assure presence of blood. Another problem with luminol is that the reaction may destroy other evidence in the crime scene. For this reason, investigators use luminol only after all other evidence has been collected, and all other investigative options have been explored (How Stuff Works, 2002).

DNA Extraction

Once the physical evidence has been collected, the DNA has to be extracted. Human nuclear DNA (nucDNA) is normally used. In some cases, a sample may be old, and the nucDNA deteriorated. Mitochondrial DNA (mtDNA) can then be used. Both forms of DNA are extracted by the same process, allowing for DNA profiling to be carried out. The sample cells are ruptured and lysed, using a detergent such as Sodium Dodecyl Sulfate (SDS). Proteins in the cellular contents are broken down using an enzyme such as Proteinase K. The DNA is then removed by alcohol precipitation or ultrafiltration through a specialized membrane. The isolated DNA sample is then ready to be profiled. If the profile determines even one difference, a match between samples can be ruled out. If a match is determined across all of the tested loci, then the results may undergo further analysis and be presented as evidence in court (Isenberg and Moore, 1999).

CHAPTER 3: LANDMARK DNA COURT CASES

Today, the use of DNA fingerprinting has risen to pre-eminent status in the field of forensic science. In terms of physical evidence in a court of law, DNA fingerprinting is both unquestioned and unparalleled, providing almost virtual certainty for either prosecution of criminal actions or freedom for the innocent.

All this has transpired since the 1980's when it was first used in criminal cases. In the intervening period between the first uses of DNA fingerprinting and the early 1990's the courts have battled back and forth, ironing out whether and to what extent the procedure could and should be relied upon as a forensic tool.

Ultimately, not only did DNA fingerprinting become established as a reliable method for analyzing physical evidence, but it became so well established that it can now be the sole physical evidence in a court case. While this is true, the path that was taken towards this point was both long and uncertain. The battle for the acceptance of DNA fingerprinting as evidence has often switched back from one trend to the other.

In law these trends and directions are decided by a procedure of evolution that is controlled by precedents. These precedents are the boundary lines, whose placement is defined and redefined by certain landmark court cases that venture into new territory and attempt to define rules for an individual case. These cases are intrical to a complete understanding of how DNA fingerprinting became established as an accepted procedure in U.S. courts.

1923, Frye v US

The Frye decision took place decades before the DNA fingerprinting procedure became an issue, but the decision did lay down rules on the use of a scientific technique as evidence that would affect many cases to come.

The defense for James Frye attempted to use a then very new polygraph test to prove Mr. Frye's innocence. (Nordberg, 2003) Although Frye passed the test, the prosecutor disputed the admissibility of the polygraph as forensic evidence on the grounds that this new scientific technique had not gained general acceptance in the scientific community.

> *"Numerous cases are cited in support of this rule. Just when a scientific principle 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."* (Nordberg, 2003)

The case was appealed, and the appellate court sustained the original prosecution's objection, disallowing the lie detector test in the courtroom.

This created a new set of rules (which later became known as the Frye standard) for the admission of technical evidence based upon "general acceptance" of the technique in the scientific field. Meaning that anyone who wanted to introduce a new scientific technique had to demonstrate conclusively that it had gained acceptance in the associated field. However, the acceptance rule provided no specific standards or procedure for determining this. This new standard was both a rigid requirement for admission of technical evidence and a loosely defined one, but it did set the standards for decades hence.

Federal Rules of Evidence 702

Rule 702 governs the admissibility of evidence in federal courts, meaning that it can override the Frye precedent in relation to technical evidence. The Frye ruling set a substantial hurdle for the admission of scientific evidence, which was difficult to actually achieve in real court cases. Rule 702 swung the pendulum back the other way:

"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."("Rule 702", 2000)

This rule defined requirements for a broader range of evidence, merging the rules for all specialized knowledge. It specified three listed requirements for the admission of any specialized expert testimony, extending to a scientific technique that supports said testimony. The scientific technique needs to be a verifiable procedure, applied on sufficient facts of the case for that procedure, and the witness must apply the procedure correctly. Proving validity is easier to achieve than having to prove general acceptance of the scientific procedure. It allows the judge in the case more discretion in admitting scientific evidence.

1985, Downing v US

John Downing was accused of defrauding a number of vendors through a front company known as the Universal League of Clergy (ULC). Mr. Downing would visit national trade shows and attempt to purchase products from multiple vendors on credit,

supplying the vendors with a list of credit references for the Universal League of Clergy. These references were various mailing addresses owned by the ULC, so the company would simply report its own impeccable record when solicited. (Becker, 2003) The crux of the matter was that the case against Mr. Downing relied completely on the testimony of twelve eyewitnesses naming John Downing as his alias the Reverend Claymore. The defense for Mr. Downing hoped to introduce an expert presenting evidence showing that eyewitness testimony is unreliable based upon the short amount of time they had to interact with the Reverend (5 → 45 minutes) and the substantial amount of time between their interaction and the their testifying. (Becker, 2003)

This attempt was denied and Mr. Downing was convicted. Mr. Downing appealed and was granted a second trial (which he also lost). The first court dismissed the request on the basis that such an expert testimony could not meet the helpfulness standard of Federal Rule of Evidence 702, but the appellate court found that:

"We hold that the district court erred. We also hold that the admission of such expert testimony is not automatic but conditional. First, the evidence must survive preliminary scrutiny in the course of an in limine proceeding conducted by the district judge. This threshold inquiry, which we derive from the helpfulness standard of Rule 702, is essentially a balancing test, centering on two factors: (1) the reliability of the scientific principles upon which the expert testimony rests, hence the potential of the testimony to aid the jury in reaching an accurate resolution of a disputed issue; and (2) the likelihood that introduction of the testimony may in some way overwhelm or mislead the jury. Second, admission depends upon the "fit," i.e., upon a specific proffer showing that scientific research has established that particular features of the eyewitness identifications involved may have impaired the accuracy of those identifications. The district court's assessment of these factors will guide its discretion in deciding whether to admit the evidence under Fed. R. Evid. 702, which contemplates a liberal view toward the admissibility of expert testimony generally. The district court's ruling under Fed. R. Evid. 702 will be reviewable under an abuse of discretion standard. Finally, the district court retains discretionary authority under Fed. R. Evid. 403 to exclude any relevant evidence that would unduly waste time or confuse the issues at trial." (Becker, 2003)

Using this new helpfulness standard, the appellate court found the expert testimony (saying that eyewitness testimony is not valid) to be non-reliable, so the expert did not testify, the eyewitness testimony stood, and Downing remained guilty. This decision introduces greater consideration of the pertinence and prejudicial value of the expert testimony than the Frye ruling allows. The ruling was another step towards a more lenient acceptance of scientific evidence, leaving the Judge with the ultimate discretion, while giving more definition to Rule 702.

1988, Andrews v Florida

This case marked the first time that DNA evidence was used in a U.S. criminal trial. Tom Andrews was accused of committing a string of rapes. With fingerprint evidence at the last crime scene, there was enough evidence to convict Mr. Andrews on the last crime. (Ramsland, 2003) Hoping to increase the sentence of the defendant, the prosecution decided to apply DNA fingerprinting to the physical evidence from the earlier crime scenes; which produced a match in each case. In this trial, the argument to allow the results of the DNA fingerprinting as evidence was bolstered by a mountain of scientific evidence, and eventually succeeded. However, that trial ended in a hung jury, but Mr. Andrews was retried and convicted the second time. At the end of the second trial, DNA fingerprinting had played a large part in the conviction of a criminal and was validated as a viable forensic technique. (Ramsland, 2003)

1989, Castro v New York

Jose Castro was accused of murdering his neighbor and 2-year-old daughter. A blood stain on Mr. Castro's watch was examined for DNA fingerprinting evidence. In this case the defense attempted the first real challenge to DNA fingerprinting. They did not challenge whether it was accepted, but how it was performed, and if it was done reliably and correctly. ("DNA Wars", 1996)

In the pre-trial hearing the court reexamined the admissibility of DNA fingerprinting and found that it was an accepted scientific technique, but that in this case the test was not performed correctly, so the DNA evidence against Mr. Castro could not be used. Also, the prosecution has the burden of proving that the test was performed properly. ("DNA Wars", 1996) The case actually never went to trial, Castro pled guilty.

In the wake of the exclusion of the DNA fingerprinting technique, a set of established procedures for DNA fingerprinting were needed; forcing the FBI to create a Technical Working Group for DNA Methodology TWIGDAM, to determine these procedures. ("DNA Wars", 1996) Also, a new 3-prong test was established to determine the viability of DNA fingerprinting evidence, taking into account if the scientific theory behind the procedure is valid, if the procedure returns verifiable results, and if the procedure was performed correctly. This gave needed definition to the rules for admissibility. Even though it denied the DNA evidence in this specific case, it accepted DNA fingerprinting as a forensic technique and refined that technique. However, this did serve to set the trend toward limiting the admissibility of DNA fingerprinting, never again would DNA evidence enter uncontested in a U.S. court.

1990, Two Bulls v US

This case further defined the admissibility of DNA fingerprinting by creating a larger test that balanced many rulings between the Frye decision and Rule 702. The resulting test has five parts. The first part is old Frye general acceptance standard. Then taking part of the Castro ruling, the second part requires the specific procedure to also be generally accepted and the third part requires that the test be performed correctly. The fourth and fifth parts of the test are a balancing act, weighing the prejudicial effect on the jury against the probative value of the evidence. This ruling was a step back from the Castro ruling, heading towards freer use of the DNA fingerprinting technique.

1991, Miles v Illinois

Reggie Miles was accused of attacking a woman. In this case the Cellmark Laboratory tested the evidence, and DNA fingerprinting produced a match with Mr. Miles. The prosecution attempted to admit this evidence in court, under the new five point test. The defendant contested this admission in many of the same ways as in Castro v. New York.

The court ultimately found that the procedure was performed correctly, met all the standards of the new test, and was thus admitted as evidence. This resulted in the conviction of Mr. Miles. The ruling in this case served to support the new procedures and guidelines created by TWIGDAM and bolstered the case for using DNA fingerprinting, as performed in that manner, under the new test and procedures.

1993, Daubert v Merrell Dow Pharmaceuticals

The mothers of Jason Daubert and Eric Schuller had taken a nausea drug, Benedictine, while pregnant. The children suffered birth defects and the parents believed that the drug was the cause of this. The parents then sued Merrell Dow Pharmaceuticals Inc., (the company who made drug) for the effects to their children. ("Daubert v. Merrell Dow Pharmaceuticals", 2003)

The case was tried in federal court. The defense for the drug company brought an expert witness to testify that there is no evidence that Benedictine caused birth defects in humans. The prosecution intended to counter with its own expert witness that would testify that Benedictine had been proven to produce birth defects in animals, and that drugs similar to Benedictine had produced birth defects in humans. ("Daubert v. Merrell Dow Pharmaceuticals", 2003) The judge in this case refused to allow the prosecution's expert witness, and based that decision on the Frye ruling "general acceptance" test. The appellate court agreed with this ruling. However, the Supreme Court struck it down, stating that:

"The merits of the Frye test have been much debated, and scholarship on its proper scope and application is legion. Petitioners' primary attack, however, is not on the content but on the continuing authority of the rule. They contend that the Frye test was superseded by the adoption of the Federal Rules of Evidence. We agree... Here there is a specific Rule that speaks to the contested issue. Rule 702, governing expert testimony, provides: "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." Nothing in the text of this Rule establishes "general acceptance" as an absolute prerequisite to admissibility. Nor does respondent present any clear indication that Rule 702 or the Rules as a whole were intended to incorporate a "general acceptance" standard. The drafting history makes no mention of Frye, and a rigid "general acceptance" requirement would be at odds with the "liberal thrust" of the Federal Rules and their "general approach of relaxing the traditional barriers to 'opinion' testimony." Beech Aircraft Corp. v. Rainey, [488 U.S. 153, 169 (1988)]. Given the Rules' permissive backdrop and their inclusion of a specific rule on expert testimony

that does not mention "general acceptance," the assertion that the Rules somehow assimilated Frye is unconvincing. Frye made "general acceptance" the exclusive test for admitting expert scientific testimony. That austere standard, absent from and incompatible with the Federal Rules of Evidence, should not be applied in federal trials."("Daubert v. Merrell Dow Pharmaceuticals", 2003)

This ruling clearly stated that Rule 702 held dominance over the Frye ruling in federal court, and that a strict "general acceptance" standard for admissibility could not be applied there. This headed more towards the inclusion of DNA fingerprinting evidence in federal trials.

Conclusion

The battle for the rules of admissibility was waged in the following manner: Precedent was established by specific landmark court cases, which defined the boundary lines of what a judge could reasonably include or exclude as evidence in a court of law. Ranging between the exclusion weighted Frye ruling and the inclusion weighted Federal Rule of Evidence 702, these cases settled those boundary lines to where they remain currently.

Today, when performed correctly, DNA fingerprinting has been firmly established as a verifiable forensic technique through thorough and repeated probing in court, sometimes forcing improvements on the procedure itself. This has been done so effectively that DNA fingerprinting evidence is considered reliable enough to be main staple of physical evidence in a court case, even convicting or exonerating the accused by itself on occasion.

CHAPTER 4: SENSATIONAL DNA CASES

DNA fingerprinting has been firmly established as a verifiable forensic technique. The path towards that was slow and uncertain, but low profile, landmark cases of great legal importance set the boundary lines for acceptance of DNA fingerprinting evidence in court. These individual cases represented battling trends for the inclusion of technical evidence, and more specifically new scientific evidence. This eventually settled into the current state of affairs, where DNA fingerprinting carved out its dominant position, both in the courts and the minds of the general populace. It is now regarded as evidence that can be relied upon when performed correctly as with regular fingerprinting or dental impressions.

The importance of DNA acceptance in court is tempered by the degree to which the general populace believes they can accept and trust this evidence. In terms of gaining acceptance in the minds of the general populace, sensational, high profile cases play a significant part in effecting the general consciousness.

These sensational cases tend to be highly visible, practical examples of the new law formed out of many low profile, landmark court cases. The sensational cases also tend to reinforce the decision of the landmark case that supports it. This helps to cement the associated trend and further define how the evidence may be used.

1954, Sam Sheppard

Sam Sheppard was accused of sexually assaulting and murdering his wife. There was a trail of blood leading from the bedroom and a smear of blood on Mr. Sheppard's pants and a nearby closet door-handle. The prosecution claimed the blood smear came

from the knife that Mr. Sheppard allegedly used to kill his wife. The defense for Mr. Sheppard presented an involved story about struggling with an intruder. Mr. Sheppard was convicted in the original trial, but in 1966 the case was overturned and Mr. Sheppard was released. (Butterfield, 1998)

Recently in 1997, the blood evidence was tested using DNA fingerprinting technology. The results excluded Mr. Sheppard as the murderer based on the blood and seminal fluid evidence. ("Sheppard's son loses suit", 2000) The same evidence found that Richard Eberling, a secondary suspect that was a window washer at the Sheppard household, could not be excluded as the murderer. (Butterfield, 1998) While this could not conclusively prove that Mr. Eberling was the real murderer and convict him, it did prove Mr. Sheppard's innocence in a highly controversial case.

1965, Albert Desalvo

A criminal, dubbed the "Boston Strangler" by the media, murdered 11 women in their homes between 1962 and 1964. In 1965 Albert Desalvo confessed to the crimes and was convicted for them. In 1973, Albert Desalvo was killed by a fellow inmate, while in prison. (Lavoie, 2001)

The body Mary Sullivan (the last of the serial victims) was exhumed and tested using DNA fingerprinting in 2001 in an effort to determine whether Albert Desalvo was "The Boston Strangler". This test found evidence of a man other then Mr. Desalvo and no evidence of Mr. Desalvo. (Lavoie, 2001)

The Desalvo family claims that this proves Mr. Desalvo is innocent of all 11 murders and is not "The Boston Strangler". However, this could also mean that Mrs.

Sullivan was incorrectly lumped in with the other 10 victims of the real "Boston Strangler" and was murdered by some else. This does, however, stand as a high profile example of how DNA fingerprinting can be used to prove the innocence of someone who has already been convicted of a crime.

1991, William Kennedy Smith Rape Trial

William Kennedy Smith was accused of raping Patricia Bowman. At the commencement of a date at the Kennedy household, Patricia Bowman claimed that Mr. Smith assaulted her. (Matoesian, 1998) In this case, there was a lack of DNA evidence that would prove rape. At the end of the trial Mr. Smith was acquitted of the charge of rape. This is an example of the pervasiveness of DNA evidence. Now that the admission of DNA fingerprinting evidence is a fact of contemporary court cases, the lack of such evidence in a situation where it would be expected bolsters the argument for the defense.

1995, The O.J. Simpson Murder Trial

Nicole Brown Simpson and Ron Goldman were murdered in their home in a brutal and bloody fashion. As such, this case was blessed with a plethora of DNA evidence. O.J. Simpson, being the ex-husband, was immediately wanted for questioning by the police. At Mr. Simpson's home a blood stain was found on the door of the white ford bronco truck in his driveway, along with a good deal more inside the truck. A trail of blood led into his house, and on his property one bloody glove was found. At the scene of the crime it was determined that the murderer bled outside the gate and left the second bloody glove beside the bodies. DNA fingerprinting determined that the blood in

the bronco belonged to both victims and blood at the scene matched that of Mr. Simpson. (Ramsland, 2003)

The overwhelming physical evidence was fairly damning, and the defense had no recourse but to wage an all out war against how the DNA evidence procured in this case. When one of the scientists that handled the evidence questioned the way in which it was packaged, they questioned the way in which it was collected and processed. The trial turned into a question of the corruption and incompetence of the police department that first came in contact with this evidence. Questions of planting evidence and contamination of that evidence were raised.

The end result of this criminal trial was that Mr. Simpson was acquitted of the murder. However, in a civil trial following shortly after this case Mr. Simpson was found liable for these murders based upon the same evidence. The result of a case with so much physical evidence being met with a contrary verdict could not be helpful to the use of DNA evidence, but it does not seem to have harmed it substantially either. The jury dismissed the evidence because of incorrect manner in which it was collected and handled, not because they did not believe in DNA fingerprinting in general. DNA evidence remains strong when the procedures are followed properly. Some view this trial as an anomaly, with the right balance of the celebrity of the defendant and incompetence of the police department, when the civil decision is considered.

1996, Monica Lewinski Scandal

President Bill Clinton, was accused of having a sexual relationship with a white house intern. At first the President denied the charges, until DNA evidence on a dress,

was presented in connection with this allegation. ("Under The Microscope", 1998) Soon afterwards the President admitted to the charge. This is not specifically a court case, but it demonstrated the power of DNA fingerprinting evidence in a very high profile scenario. DNA evidence is so highly regarded that it was used as one of the main pieces of evidence in an attempt to impeach an American President.

2001, Michael Skakel

In 2001 Michael Skakel was tried for the murder of Martha Moxley, allegedly committed, in 1975. The victim was murdered at her home, with a golf club belonging to the accused parents. DNA fingerprinting tested evidence of semen, blood, and skin under the deceased fingernails; each being unable to provide a link to Mr. Skakel. He was eventually convicted on circumstantial evidence, eyewitness testimony placing him at the scene, and his own statements. The result of this case serves to show that when not sufficiently conclusive, DNA evidence can be discarded.

2003, Carl Dotson Murder Trial

Carl Dotson and Patrick Dennehy both played college basketball at Baylor University. A few weeks after Mr. Dotson moved in with Patrick Dennehy, Dennehy's body was found in rock quarry in Waco, Texas. ("Search for physical evidence continues", 2003) Carl Dotson is currently charged with the murder of Patrick Dennehy. This would most likely not be the case without DNA fingerprinting evidence. The body of Mr. Dennehy was found in a badly constituted state and could only be identified by the use of DNA fingerprinting. As it stood, the accused was arrested in his home state of

Maryland. Who knows if the authorities could have found cause to arrest Mr. Dotson without the ability to identify the body, or whether he would have fled the jurisdiction.

2003, Scott Peterson Murder Trial

In December 2002, Scott Peterson's pregnant wife disappeared and after a number of months was assumed dead. Mr. Peterson was arrested in connection with case, under the suspicion that he murdered his wife. Later the bodies of a mother and child were found in a lake that Mr. Peterson admitted visiting around the time of his wife's disappearance. ("Scott Peterson booked", 2003) However, without DNA fingerprinting that may have been as far as things proceeded.

The bodies had been submerged in water for months and lacked dental records or any semblance of a normal type of identification. DNA fingerprinting was used to determine the identity of the body. Without conclusive proof that the alleged victim was murdered, such as the body, many cases are simply left open, such as missing persons. Now, DNA fingerprinting is trusted as reliable enough to suffice as the only method of identification.

2003, Kobe Bryant Rape Trial

A well-known national basketball player Kobe Bryant, was accused of raping a 19 year old woman in Colorado while he was awaiting orthoscopic knee surgery. Allegedly, Mr. Bryant invited the woman to his hotel room, she agreed, and when in the room he attacked her. (undeclared, Fox News, 2003) In the absence of witnesses, DNA evidence, or strong physical signs of abuse, such a case usually turns into a "he said, she said"

matter. This is most especially true when it concerns a person with a high-profile image that is well known to the mass media.

In fact, when the matter first broke, Mr. Bryant used his previously clean, high-profile image to claim that there had been no relations of any kind with the young woman. Only after DNA evidence surfaced proving conclusively that there had at least been a sexual act of some kind, did Mr. Bryant admit to that part of the matter, and change tactics to contending the sex was consensual. Lacking DNA evidence, the matter may have not gone to trial. Thus, it has changed the dynamic of such events.

This case also demonstrates a potential use of DNA for exoneration. Recently, the defense has found DNA evidence that a third person had sexual relations with the accuser within one to three days of the alleged assault. ("Compelling Evidence", 2003) This evidence shows that there may be a second suspect for the assault. This presents a possible tactic in the creation of reasonable doubt for this trial. So, DNA fingerprinting has changed the dynamic of this situation in both directions.

Conclusion

Behind the scenes, landmark court cases turn out to be the defining events of importance that change the law and allow new evidence to be first introduced and presented in court, paving the way for admission in future cases. However, these sensational cases serve as examples of the usefulness of DNA fingerprinting evidence and through them ingrain that usefulness, reliability, and the power of this evidence into the general mindset. That is the process through which DNA evidence gained acceptance, not only in the legal system, but in the culture and public at large.

From condemnation to exoneration, DNA fingerprinting evidence was proven time and again in these media-centric cases to be an effective tool for reaching a greater level of information and introducing that to court cases. It has been used to identify the guilty, prove the innocence of those wrongfully convicted, and even employed as a new tool for divining new reasonable doubt. In fact, even its lack of persuasiveness in the Simpson murder trial served to expose incompetent methods used by the police in that case.

Ultimately, every public attempt further cemented the relevance of DNA fingerprinting both into the legal system and in the culture, paving its way towards general acceptance.

CHAPTER 5: DNA DATABASES

As technology has advanced, so have many of the moral issues that come with it. Humans have been trying to learn everything there is to know about themselves, and part of that includes understanding what makes everyone the way they are. After the discovery of DNA as the main building block for life, scientists have worked hard to begin our understanding of its function; this has led to such endeavors as the human genome project. Today with scientists advanced understanding of humans and their DNA, it has become possible to differentiate between people by simply obtaining a sample of their DNA. Although this ability to distinguish individuals has excellent applications for forensics, DNA analysis has the potential to reveal much more about an individual than whether or not his DNA was present at a crime scene. DNA analysis can also be used to determine a person's genetic predisposition to certain diseases. This has raised many worries that a DNA sample donated to a DNA database for forensic or testing purposes could lead to someone being denied health or life insurance, which brings up many ethical issues. Recently databases have been made that contain DNA samples for use in court cases, and for fighting crime. At the same time this has brought up these ethical issues and concerns.

Part of the problem with using DNA fingerprinting for databases is that people are not fully informed about what is being done, thus the average individual is against the formation of such databases, even when they can be used for the public's good. Because the vast majority of people's DNA are identical (this is what makes us human), only

specific portions differ between individuals. This "unique" DNA is often termed "junk DNA" because it codes for nothing useful, otherwise it would have been conserved in nature. So this "junk" DNA is what is analyzed in forensics. From an ethical point of view, the key point with DNA databases is whether medical information can be obtained from an analysis of junk DNA. If the answer is no, then so long as only junk DNA forensic information is placed in the database, then no medical information can be obtained from it, and the public's fears are ungrounded. In addition, ways exist for making donated DNA samples anonymous, so database information can not be traced back to specific individuals. With this in mind, it becomes a lot more acceptable for people to agree to DNA sampling, once they know that they won't become subject to anything such as losing their insurance, or being biased against during job interviews. It is important that people become informed of this, and helped to understand what this information can and will be used for.

Right now, the main use for DNA databases like the FBI's CODIS database, has been to help catch repeat offenders in crimes. In some states, such as Florida, they have passed into law that all criminals convicted of certain felonies must give a blood sample for the DNA database. This makes it possible for police to catch a repeat offender much more easily, since all it takes is to find a DNA sample at the crime scene, and if it matches a previously convicted felon, the criminal is easily identified and arrested. This shows the importance that DNA profiling is fast becoming a useful tool for identification (Zurer, 1994). The best part about this is how easy it is to get a sample of someone's DNA at a crime scene. As seen in movies or TV shows, all that is required to get a DNA sample is a strand of hair, a drop of blood, or something as small as a flake of skin that

fell off of the suspect. This method for catching criminals and taking DNA samples has worked very well for many areas since it is statistically shown that most criminals go back to a life of crime when released from jail. DNA databases have also been used to help solve old cases when tissues have been preserved, or to link crimes from different states together, as well as help to exonerate the innocent, including saving some people from death row. In fact, based on the way DNA fingerprinting is performed, it is easier to prove "exclusion" (a non-match) than to prove a match (Crime Gene Investigation, 2001).

One of the problems encountered in a courtroom with DNA evidence is determining the probability of a match. Is the likelihood of a match between a crime scene sample and the suspect one in a million, or one in 10 million, or one in a billion? To determine this, it is very important to know the frequency of specific alleles (versions of a gene) in the human population. Every person has different allele frequencies these are what make it possible to differentiate between two DNA samples and these are what make DNA databases useful. By collecting more DNA samples from people it becomes easier to make an extrapolation from frequencies in the database to frequencies in the general population (Snell, L., 2003).

Careful attention must also be paid to race in database analysis, especially if the allele frequencies are substantially different between races. For example, analysis of a specific allele frequent in the Hispanic population may lead to the false conviction of a Hispanic suspect when in fact most Hispanics would match the analysis. Thus it is important to obtain allele frequency information for specific populations of individuals to

strengthen the information we can derive from DNA analysis. Currently race is not being considered in the DNA databases, but one reason for that is that there aren't enough entries to make it worth the effort. Only a few other countries have begun to make DNA databases, and as of right now there is no sharing of data, but in the future there may be, so as to make it possible to get a more exact prediction on possible matches. However some people feel this is going back on all of the efforts that have been made to erase racial discrimination, and that this will encourage racial profiling.

Like nearly everything else in the scientific world, nothing about DNA fingerprinting is 100% assured. The term DNA fingerprint is, in one sense, a misnomer: it implies that, like a fingerprint, the VNTR pattern for a given person is utterly and completely unique to that person. Actually about 7 people in the world have your hand fingerprint. And likewise, many people can share the same allele at a particular DNA locus (location). Actually, all that a VNTR pattern can do is present a probability that the DNA from the suspect is the same as that from a crime scene. And to increase the odds, usually in forensics several (11-13) loci are analyzed so their probabilities can be multiplied together (Brinton and Lieberman, 1994).

Currently, the world's largest DNA database is the U.S. FBI CODIS. This database is a network of local, state, and national databases with DNA entries from the criminal population, and from crime scenes. CODIS can be found in 114 laboratories across the United States in 43 different states. There are more laboratories that do DNA testing, but these 114 labs are the ones that currently have the software of CODIS in their laboratories. As an example of CODIS in action, Tampa may have an unsolved rape case

that they're working on. They get a DNA profile from the victim of that unsolved rape case and they can compare it, using CODIS, to DNA profiles from previously convicted felons to see if this is a repeat offender, and also to samples collected from other crime scenes to see if the crime might be linked to others. They can also send that unsolved rape case profile to the state database system for Florida and ask that the unsolved case be compared against any other unsolved case in Florida or against all convicted-offender samples that are within the State of Florida. Then if no matches are found, that sample can be forwarded on to the National DNA Index System, NDIS, and compared against any state that contains profiles for other unsolved crimes or for convicted offenders. Currently all 50 states aren't a part of NDIS. Slightly more than half of the states are currently a part of NDIS, but soon, through the work of the FBI and state governments, many more states will be on line nationally (DNA Databases, 2000). For DNA databases to become more accepted it will be important for the amount of errors to be reduced when taking and processing DNA samples. While new technology helps to lower the chances of an error, they still occur, and it is important for it to be pointed out in court cases that while the chances for a false DNA match between the suspect and the crime scene might be 1 in 1,000,000 that there could be a 1 in 500 chance that there was an error that occurred in the DNA testing process. So in the most important cases, it has become common to have the DNA tested at multiple labs which compare data.

Increasing the size of DNA databases is controversial because of civil liberties worries, is the latest phase in the rapid growth of the use of the genetic code in U.S. law enforcement an invasion of privacy? All 50 states have enacted laws to force the collection of DNA samples from inmates convicted of sex crimes. In 1998, only five

states had passed laws requiring that some or all convicted felons be tested. That number had grown to only seven by 2000. In the 2 1/2 years since, 28 states have passed such legislation. Bills under wide consideration would expand the DNA sampling list to include all convicted felons. The idea is backed by the FBI, police chiefs, district attorneys, crime labs and victims' groups (Ballard, 2003). The army also takes DNA samples of soldiers so that they will be able to identify a body if it is wounded beyond recognition. Perhaps the army's databases could be used with the criminal database to help research in the area progress. Also it may be possible for people who give blood to the Red Cross to be asked to donate a small portion of their blood to help databases become more inclusive. These are just a couple of the ways in which DNA databases could be expanded thus making it possible to get better statistical numbers and increase its usage in important trials. Using DNA in court is becoming more and more common, but before it can become widely accepted and used it will need to be expanded through DNA databases and better explained to the public to prevent any distrust in the system.

CHAPTER 6: CONCLUSIONS

The amount of material needed to determine the difference between two people has become increasingly small. This difference can be determined using something as small as a drop of blood. Using a small amount of blood, skin, or hair, a person's DNA can be obtained. DNA base pairs are arranged differently among people, these variations between people are called polymorphisms. Polymorphisms are found throughout the human genome, but are used in forensics when these differences repeat one to thirty times in a row, called variable number tandem repeats, or VNTRs. A DNA fragment's length is determined by the number of repeats present in a VNTR, and the number of repeats varies between individuals. The chemical structure of DNA does not vary from person to person, only the sequence, and number of repeats. In theory, every person could be identified by their DNA sequence, but because of the large number of base pairs in each DNA molecule it would be extremely time-consuming to use complete an individual's entire DNA sequence for identification. Instead, scientists have used the repeating patterns of DNA to create a short-cut identification method. A small carefully chosen portion of the DNA (a locus) can be analyzed to determine the probability of a match between two samples of DNA.

DNA fingerprinting is commonly used for criminal identification, paternity and maternity testing, and personal identification. In criminal investigations and forensic sciences, tissues such as blood, hair, skin cells and bodily fluids can been used to isolate DNA. The DNA on the evidence is then compared to the DNA of the suspect to see if the VTNR patterns match. Homicide investigators use VTNR patterns to establish identity of

victims when facial reconstruction is not possible, and hand fingerprints are not available. VNTR patterns are so specific that it is possible to reconstruct a parental pattern even if only the child's pattern is known. This type of analysis is commonly used when the father's identity is in question.

Although DNA fingerprinting is a useful tool for many applications, it is not 100% accurate. The name 'fingerprint' is somewhat misleading because single VNTR patterns are not really unique to each person. One in 30 people may share the same allele at a give location, so it is important to analyze 11-13 loci to be able to increase the odds. The probability of identification based on VNTR patterns is usually very high so long as many loci are analyzed, but based on evidence and the circumstances surrounding each case, the probability can vary. One main issue affecting the validity of DNA fingerprinting is the quality of work of those involved with the case. Sloppy or careless work or involvement of a worker who has not been properly trained can greatly influence the accuracy or believability of the results. Depending on the number of loci analyzed, there is also a chance that two unrelated people will have the same fingerprint. The more probes used, the better the odds that no two unrelated DNA samples show the same fingerprint (Reynolds, W., 2003). DNA forensics begins at the scene of the crime and, if evidence is correctly collected, can establish a link between a crime and involved individuals. It is the evidence collected using forensic science that is used to incriminate a possible suspect. DNA collected at crime scenes is the most important evidence because it can prove without a doubt that a particular suspect was present at the crime. The method of collection, however, can also determine whether the court will allow the

evidence to be used during the trial. Carelessness by scene investigators could result in a guilty criminal being allowed to walk free or an innocent person jailed.

Behind the scenes, landmark court cases turn out to be the defining events of importance that change the law and allow new evidence to be first introduced and presented in court, paving the way for admission in future cases. Alternatively, sensational cases serve as examples of the usefulness of DNA fingerprinting evidence and through them ingrain that usefulness, reliability, and the power of this evidence into the general mindset. That is the process through which DNA evidence gained acceptance, not only in the legal system, but in the culture and public at large. From condemnation to exoneration DNA fingerprinting evidence was proven time and again in these media-centric cases to be an effective tool for reaching a greater level of information and introducing that to court cases. It has been used to identify the guilty, prove the innocence of those wrongfully convicted, and even employed as a new tool for divining new reasonable doubt. In fact, even its lack of persuasiveness in the Simpson murder trial served to expose incompetent methods used by the police in that particular case. Ultimately, every public attempt further cemented the relevance of DNA fingerprinting both into the legal system and in the culture, paving its way towards general acceptance. This acceptance leads to DNA fingerprinting as a very useful resource. Even though it is still in its infancy, it could become an incredibly valuable, and one of the most important tools to provide evidence for innocence or guilt, but until it becomes something better understood, and more publicly recognized, it will not be able to be used to its highest efficiency and potential.

In order to determine the probability of a DNA match, the uniqueness of each DNA locus analyzed needs to be determined. But how do we really know that a particular number of repeats (say 7 repeats) at site "X" are found in only one out of 30 people? To determine this, the frequency of the allele needs to be determined. And to do this we need DNA databases. DNA databases could become one of the most useful and effective tools for crime prevention, but before they will be accepted by the public many steps need to be taken. Communication between scientists who create such databases and the general public who may provide samples to the database needs to be increased.

Larger databases will increase the accuracy of matches, and criminals that commit crimes in many different areas as well as repeat offenders will be easier to catch. With increased public knowledge, hopefully people will be more willing to understand and accept DNA fingerprinting in court cases, and the need for DNA databases to improve the technique.

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