03E031I

03E031I

IQP-52-DSA-3310
IQP-52-DSA-3602
IQP-52-DSA-0789

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

By:

David Argue

John Plunkett

Kai Rasmussen

August 27, 2003

APPROVED:

David S. Adams

Prof. David S. Adams, Ph.D.
Project Advisor

Abstract

The purpose of this IQP was to investigate the complex technology of DNA fingerprinting, and document the impact of this relatively new technology on society via legal and ethical issues. Although it has been called the greatest forensic tool in the history of forensic science, the acceptance of DNA fingerprinting technology in courts was not a straightforward process. By looking at how DNA was discovered, how the DNA forensics made its way into the legal community, and at how it is currently used in forensic science, we will show that DNA forensics has become an accepted science

Table of Contents

Executive Summary

DNA or Deoxyribonucleic acid is a polymeric molecule that is composed of four different building blocks. These four different bases are adenine, cytosine, guanine, and thymine (A,C,G,T respectively). The human genome is a string of DNA with about 3 billion bases. A specific piece of DNA can be identified by a string of these bases. For example it is perfectly acceptable to write AATTCGTCCAAAA to describe a piece of DNA.

Currently, there are three main methods to perform DNA fingerprinting. The methods are RFLP, PCR, and STR. The RFLP method, which stands for *restriction fragment length polymorphism*, uses restriction enzymes to divide up a DNA molecule into fragments that can then be examined to identify changes in length and composition between individuals. The sections of DNA analyzed with RFLPs are usually non-coding sequences of highly polymorphic base pairs.

The second method commonly used to analyze DNA is called PCR or *Polymerase Chain Reaction*. This technique is used to amplify DNA when small amounts are present at a crime scene. There are three basic steps in PCR. First, DNA is heated to near boiling to denature it to single strands that are available for hybridization. Second, the reaction is cooled to allow primers specific for certain sites on the DNA to hybridize to the single stranded template DNA. Third, at a third temperature optimum for Taq polymerase added to the reaction, the polymerase entends the primer sequences to make two new strands of DNA. These three steps are repeated as many times as is necessary.

The technique used most often for analyzing DNA nowadays is called STR, *short tandem repeats*. These short stretches of DNA vary in lengths between individuals, and are short enough to be easily amplified by PCR, so very little material can be analyzed. Because

the sizes of the STR bands are easy to determine on a gel, no restriction enzymes are required, or radioactivity for probe hybridization. Because some STRs are relatively common, several STR loci are usually analyzed to increase the uniqueness of the analysis. For this reason the FBI currently requires 13 different STR sites to be examined in DNA analysis.

If DNA from a crime site matches that of a suspect, there is only one of two outcomes. Either the suspect was present at the crime scene or there was a coincidence match. The current 13 STR loci chosen for a standard DNA analysis were carefully chosen because they are relatively unique loci between individuals. Before these were adopted, some loci were relatively common, and thus were the subject of much debate in forensics. Certain STR loci may be rare in the total population, but relatively common in certain ethnic populations. If STR loci common to certain ethnic groups are used in the analysis, more random matches will occur which can result in false convictions. Although the current standard 13 STR loci are quite good, they are not perfect, so ongoing efforts are focused on finding more unique loci. And experts point out that DNA forensics is far superior to eyewitness accounts.

The list of things at a crime scene that contain DNA is quite extensive: mucus, blood, sweat, semen, skin, tissue, hair, dandruff, saliva, bone, and teeth are all useful samples to be collected from a crime scene. Once DNA is discovered at a crime scene it is very important that it is collected and tagged in a way that it doesn't degrade and that it can be easily identified.

Entering complex scientific evidence into a court of law has never been a simple task. In 1923, under the Frye standard, a scientific method or principle had to be generally accepted by the scientific community to be allowed in court. In 1975, with the creation of the Federal Rules of Evidence, and especially Rule 702, it was now acceptable for an expert witness to

testify upon specified knowledge, providing that the testimony was based on reliable scientific evidence and was applied correctly.

In 1985, the helpfulness standard was created, allowing a judge to determine if testimonial evidence would assist the jury in reaching a verdict. DNA evidence and testing finally was admitted in U.S. court in the case of *Andrews v Florida, 1988*. However, this did not mean that DNA testing had been perfected. Only one year later, in *People v. Castro*, 1989, the court rejected a DNA analysis that had been improperly performed. The court developed a three-prong test to determine if DNA evidence would be admissible in a court of law. One useful outcome of the *State v Schwartz* trial was shortly thereafter, the FBI established standards for DNA analysis.

The clash between Frye and the Rules of Evidence was finally laid to rest in 1993 with the case of *Daubert v Merrell Dow Pharmaceuticals*. When the case went to the Supreme Court, it was determined that Rule 702 of the Rules of Evidence supercedes the Frye standard and that the Frye standard was obsolete. A new interpretation of Rule 702 required the trial judge to ensure that an expert's testimony is relevant and reliable, and therefore admissible.

Several "sensational" cases have brought DNA testing to the public eye far more than the above mentioned landmark cases. For example, in1802, allegations regarding a love affair between Thomas Jefferson and his slave were made. Historians have long debated the rumor that Jefferson fathered a child with one of his slaves, Sally Hemings. DNA testing was able to confirm that a member of the Jefferson family did in fact father a child with Hemings, though it could not determine which Jefferson.

DNA testing was also used to shed light on another a myth. One of the more controversial Russian folktales and legends is the story of the orphan Anastasia, the youngest

daughter of Tsar Nicholas II of Russia. Anastasia's family was murdered, though Anastasia's body was never found. A young woman surfaced who many believed was in fact the lost Duchess Anastasia. However DNA testing revealed the woman was only an imposter.

DNA testing has also helped to convince a family that Alberto DeSalvo, the man believed to be the notorious Boston Strangler, is innocent of the rape of Mary Sullivan the last victim. The confirmation has led the DeSalvo and Sullivan families to believe Alberto is not the Boston Strangler, or perhaps there were several stranglers.

DNA testing was brought to the public's attention like never before in the infamous O.J. Simpson trial, in which there were questions and allegations as to DNA evidence being tainted or inaccurate. The blood found at the crime scene matched OJ with the probability of it being a random match estimated at 1 out of 6.8 billion. In this controversial case, the defense claimed that the DNA evidence was tainted, possibly even placed there by a corrupt officer. Subsequently to this sensational case, standards have been tightened regarding procedures for DNA evidence collection and processing.

In 1990 the FBI founded the CODIS program in order to have a national criminal DNA database. This database would help solve many otherwise unsolvable crimes as well as deter convicted felons from repeating a crime. Once a felon's DNA has been entered into a database for a current conviction, he will be easily identified if he leaves his DNA again at a future crime scene. The CODIS program has been widely successful. Over the last couple of years, the database has increased immensely as well as solving literally thousands of crimes.

However, there have been many arguments over the ethical natures of these DNA databases. The American Civil Liberties Union argues a forced collection of DNA from convicted felons violates their right to privacy. Others argue that felons forfeit this right when

they commit the felony. Some argue that collecting DNA violates constitutional rights as well. Arguments have been made that medical information present in the databases will be used to deny individuals pre-disposed to medical ailments, or deny someone employment. The point that is not made clear in these arguments is that STR lengths (the information in the database) contain no useful medical information that we are aware of. Thus so long as the original DNA sample (which could be used to obtain medical information) is destroyed following entry of STR data into a database, the authors of this IQP fully support a continuation of the CODIS database project.

Project Objective

The purpose of this IQP was to examine the controversial scientific topic of DNA fingerprinting, and examine how a scientific topic can have an impact beyond the technique itself on society. Our early chapters focused on how the technology has developed and how it is being used. In order to do this we studied what DNA was and how it is collected. We also studied important court cases, issues surrounding DNA databases, and events where DNA has made an impact.

Chapter-1: Introduction to DNA Fingerprinting

There is an alarming trend in today's culture. The trend is that people use the new technology we are given without a second thought to its impact or how it works. This ends up causing a lot of problems because something that people take on face value one day can be found to have terrible side effects the next. People have become accustomed to this fact, and take things with either guarded optimism or just try and ignore any chance that a technology may fail. For this reason when people are directly faced with questions regarding technology it is very easy to shake the foundation of their knowledge and instill doubt in their minds.

Why is this important? In most cases it isn't. Most people do not know how their TV or microwave works but is that going to stop them from using them? Of course it isn't. Along the same lines, few people will have to make a serious decision that is based on how a television works so long as it accomplishes its obligation, although some people may try and make you believe that seeing a television show is the most important event that is happening in their life.

DNA fingerprinting is different than these humdrum problems. The whole concept is based on trusting in how technology works and in the most part a layman cannot even use the technology himself. First a person has to believe that DNA exists the way that scientists have told them it does. Most people do not even know much about this topic past a cursory explanation in some intro biology class. They then have to transfer this partial knowledge to a fingerprinting situation. This is usually done with a metaphor like how DNA is like a fingerprint or a snowflake, everyone's DNA is different. This requires more trust because who is going to go and spend their time trying to either prove this statement, which would

require a long and drawn out proof, or find something to disprove it. Finally after working through all the background information on DNA, the final result is applied to an interesting real world problem. With all the strikes against DNA technology it's a surprise that anyone even believes it can do what they say it can. If there ever was a topic that was easy to put a seed of doubt into people's minds it would be this.

Is there a solution to these problems? Yes, and it is pretty easy. The first thing is that the new technology has to be explained in a way that is easy to understand. The second thing is that in this explanation it will invariably show that some parts of the logic are poorly implemented and need to be expanded on.

DNA History

To understand DNA fingerprinting one must first understand DNA. The best way to do this is to start with a gene. We have known about genes since 1865 when Gregor Mendel found that different traits are determined by discrete factors that he called genes. Through experimentation he observed that genes are inherited from an organism's parents. He also noticed that genes do not blend to create intermediate stages but instead exist in specific forms (DNA From the Beginning 1, 2002). This means that if someone has blue eyes, for example, this trait would have to be inherited from the genes of one of his two parents. There is no way that the genes from one parent once mixed with the other parents would create a color halfway between the two. This is not art, yellow and blue do not equal green.

This definition worked until technology allowed people to directly chemically analyze DNA. When this was possible a new definition of a gene was created. Beadle and Tatum defined a gene as the discrete directions for making a single protein that influences a

metabolic trait (DNA From the Beginning 23, 2002). Proteins were then found to be long strings of amino acids that are arranged in a specific order. This allowed the gene definition to be refined again because noticing that proteins are in a precise sequence makes it possible that genes are also precise DNA sequences that encode a protein (DNA From the Beginning 23, 2002). Knowing that DNA exists in precise sequences, it is then possible for scientists to analyze DNA and break it down into its components to try and decide what part of DNA codes for which protein.

DNA or Deoxyribonucleic acid is a polymeric molecule that is composed of four different building blocks. These four different building blocks are adenine, cytosine, guanine, and thymine, which are also known as A, C, G, and T (Bruzel, 1998). These blocks, also known as *bases*, are the only four building blocks of DNA and will be referred to as A, C, G, and T because the nicknames are actually used more often than the chemical names (DNA Testing: An Introduction, 1998). On the surface it may appear incredible that all the information to create a human can be boiled down to a sequence of four different letters, but people have to realize the sheer number of bases that exist in the complete set of human DNA, which is also known as a *genome*. The human genome is a string of DNA with about 3 billion bases. Knowing this the 4 base system becomes more plausible (Fingered by DNA, 2001).

A specific piece of DNA can be identified by a string of these bases. For example it is perfectly acceptable to write AATTCGTCCAAAA to describe a piece of DNA. In fact using this definition a scientist who has a DNA synthesizer can actually produce a DNA strand with just this information (DNA Testing: An Introduction, 1998).

Scientists have decided that each organism has a defining set of chromosomes that contain all of its genetic information. The number of chromosome pairs varies between

organisms. Humans have 46 chromosomes arranged into 23 pairs. One chromosome from each pair is inherited from the father and one from the mother. The human genome is then defined as a set of long DNA molecules, one corresponding to each chromosome (DNA From the Beginning, 2002). Since DNA is inherited from both parents, and genes can even "hop" between chromosome pairs, there is a lot of inherited variance in DNA between different people, this number is significantly reduced when it comes to direct relatives because children for example should have nearly the exact same information as one of the parents when it comes to half of his chromosomes.

Genes, which encode all the proteins in the human body, are very important. There is an estimated 100,000 genes in the human body. However, this only accounts for 3% to 10% of all the DNA in a human's 46 chromosomes. What does the rest of DNA do? It is used in the control of gene expression, orders the structure of DNA, or has yet to be understood so is considered "junk DNA". The physiology between all humans is relatively similar, so the area of DNA that codes proteins is very similar between people. In fact differences in the gene section of DNA is the reason for inherited diseases. In that case it is logical to assume that the vast majority of varying sequences between two people's DNA occurs in the 90% of human DNA that does not code proteins. Variations in this portion of DNA do not have ill effects most of the time. For example one person could have an A at a specific location while another person has a G at that location and there would be no problem (Bruzel, 1998).

DNA Fingerprinting Methods

DNA fingerprinting technology has been around since 1985 and is still being worked on and improved. At this time there are three main methods to do DNA fingerprinting. The

methods are RFLP, STR, and PCR. All of these methods require samples of DNA to be collected in the same manner. Additionally all of the methods are based on the fact that each person's DNA is different and by looking at specific locations that are known to be highly variable it is possible to see if there is a match between two samples, say from a suspect versus a crime scene sample. Beyond these factors the three systems vary quite a deal as will be shown. The first method to examine is the older RFLP method of DNA fingerprinting.

RFLP

The RFLP method, which stands for restriction fragment length polymorphism, uses restriction enzymes to divide up a DNA molecule into fragments that can then be examined to identify changes in length and composition (Fingered by DNA, 2003). The sections of DNA that the enzymes isolate are non-coding repetitive sequences of highly polymorphic base pairs. Different segments of DNA that can be examined are called locus sites (DSMZ DNA Fingerprinting).

The restriction enzymes cut the DNA into millions of different sized fragments ranging from 100 to more than 10,000 bases long. These millions of base pairs are separated using a process called *gel electrophoresis*. In this method the DNA segments to be organized are placed onto a slab of gel agarose and then placed in an electric field. This separates the DNA for two reasons. The first reason is that DNA is negatively charged so it is drawn towards the positively charged electrode. The second reason that this will separate the different DNA segments is that since they are all different lengths the shorter ones will move through the agarose faster than the longer ones (O'Connell).

Once the DNA is separated in the agarose it has to be removed from the gel because if the DNA remains in the gel it begins to breakdown. To prevent this, the *Southern blot technique* is used. In the southern blot technique the DNA that has been separated by the agarose is transferred to a nylon membrane. After the DNA is transferred (blotted) to the nylon membrane it is permanently bonded with the nylon. Although the DNA is sorted and permanently affixed to something it is still not visible (DNA Fingerprinting 3, 2001). To be able to "see" the DNA you would then hybridize it with a radioactive probe. This means that you would take the membrane and incubate it in a solution containing a radioactive single locus probe (DNA Forensics Problem Set 1, 1996). A single locus probe would be a DNA fragment whose sequences are complementary to the tandemly repeated sequences of DNA found in human chromosomes (DNA Fingerprinting 3, 2001). After the DNA hybridizes the unbounded probe is washed away and the only radioactivity remaining in the sample is the stuff that was bound to the DNA on the membrane. While the result of the probe is still not visible to the human eye it is easy to remedy this. All that has to be done is place the southern blot next to a sheet of x-ray film in a light tight container. The radioactive decay will expose the x-ray film and the result will a dark band where the radioactivity was, which creates a bar code style page of where the DNA coincided with the probe. This x-ray film is then called an *autoradiograph.* After a single probe of the southern blot has been completed the radioactivity can be washed away with a high temperature solution that leaves the DNA in place. All that is left to do then is to hybridize the southern plot with a different radioactive probe. A set of autoradiographs, is called a *DNA profile* (DNA Forensics Problem Set 1, 1996).

How is an autoradiograph interpreted? An autoradiograph identifies which VNTR is present in a sample and where in a RFLP that VNTR's exists. A VNTR is a *variable number of tandem repeats*. The process to create the autoradiograph already dealt with VNTR's. The DNA segments that hybridized with the solution (probes) were designed to have sequences complementary to VNTRs (DNA Fingerprinting using VNTR, 1999). VNTR's are categorized into two different types. One type of VNTR is a simple repeating pattern, such as GCGCGC. The other commonly used VNTR utilizes all four of the bases. An example of this would be ATGCATCG. The repeating sequences are known as *microsatellites* and the number of repeats differs from person to person, which is what makes a microsatellite useful in DNA fingerprinting (Basic Genetics, 2001). Knowing this it becomes apparent that to read a autoradiograph all that needs to be done is put it next to the autoradiograph for another sample that used the same radioactive probe and see if the marks match up.

The RFLP method is very exact but it also takes a very long time to do with over 200 steps. This fact dictates when RFLP can be used in forensics. RFLP is expensive because there is a high chance of error with all the steps and it takes a decent amount of time to do. In a forensics case this time may mean that police could be investigating the wrong suspect, and in turn let the trail go cold for the real one (Fingered by DNA, 2001). RFLP is also a non-amplifying technique, so it takes a fair amount of crime scene material for analysis.

STR

A technique used far more often in forensics today is called STR. STR stands for *short tandem repeats*. These areas of DNA are short enough to be amplified by PCR, and the analysis simply involves running a gel to determine the lengths of the amplified bands. No

restriction enzymes are required to cut the DNA. No radioactivity is required for probe hybridization. The main difference between these two processes is that in STR you start out with a smaller DNA fragment. Instead of looking at the whole DNA strand STR merely focuses on differences in small areas of the DNA. For this reason it is not necessary to use the entire strand of DNA. With STR analysis, PCR primers are usually designed to flank a minisatellite site whose lengths vary considerably in the human population. It is then relatively straightforward to run a gel to determine the length of the DNA band amplified. The end result of a STR analysis will show the number of nucleotide repeats at a certain site. Because some STRs are relatively common (i.e. appear in 0.1% of the population) several STR loci are usually analyzed to increase the uniqueness of the analysis. For this reason the FBI currently requires 13 different sites to be examined in a STR search. STR has become favored over RFLP because it is easier and quicker to do. RFLP takes 200 steps while STR may only take about 50.

PCR

The third method of DNA fingerprinting differs greatly from the previous two. This method is called PCR or *Polymerase Chain Reaction*. The creation of the PCR method was seen as both an incredible breakthrough and a staggeringly obvious idea. The reason for this is that the PCR method utilizes the idea that DNA naturally copies itself in the right situation. There are three basic steps in PCR. First, DNA is heated to near boiling to denature it to single strands that are available for hybridization. Second, the reaction is cooled to allow primers specific for certain sites on the DNA to hybridize to the single stranded template DNA. Third, at a third temperature optimum for Taq polymerase added to the reaction, the

polymerase entends the primer sequences to make two new strands of DNA. These three steps are repeated as many times as is necessary. The normal number of cycles is between 30 and 40 times (Fingered by DNA, 2001).

The PCR method of analysis has many benefits over the Southern Blot method, including amount, invasiveness, degradation, time, disposal and gene selection. The Southern Blot method requires between 0.05 – 1.0 μg of purified DNA. This would be the equivalent of 2 hair roots, 2 to 40 μg of blood, or 25 – 500 μg of saliva. More than this would usually be required because some may be lost during the purification process. In a paternity test this much of a DNA sample would not be all that difficult to obtain, but in a forensics case it can be difficult to obtain large amounts of DNA evidence. PCR on the other hand can be done with as little as one cell. This means that PCR requires a staggering 10,000 to 200,000 time less DNA than is required for Southern Blots. This smaller amount of DNA required allows the samples to be collected a lot less invasively. PCR samples can be collected from mouthwash or hair so there is no need to draw blood from a suspect. This also alleviates people's fear of contracting HIV or Hepatitis from needles used to collect blood (DNA Fingerprinting by PCR).

Another big benefit of the PCR method is that it can work with degraded DNA. The Southern Blot method is not always clear even when performed correctly. One of the main reasons for this is that DNA degrades over time. When DNA degrades, the long strands of DNA begin to fragment into smaller strands. When enough time goes by, the fragments of DNA could be too short to appear on the agarose gel. Non-conclusive runs of Southern Blotting can require retests that require fresher DNA, which may not be available in a forensics case. PCR only needs fragments of a few hundred bases. A few hundred may seem

like a large amount but Southern Blot tests require a substantial amount of fragments that are at least tens of thousands of bases long. The difference in degradation time means that to perform a Southern blot test, fresh bloodstains would be preferred. PCR on the other hand can be used on DNA that is so degraded that it can be successfully run on the remains of a 13,000-year-old extinct giant sloth or the brain of a 7,000-year-old mummy (DNA Fingerprinting by PCR).

The amount of time that it takes to run these two different types of DNA tests is also important. A full RFLP southern blot test can take up to a week, while a PCR test can be finished in one or two days. Another benefit of PCR over Southern Blot is that PCR does not require any radioactive material so there is no need for radioactive waste disposal and containment facilities (DNA Fingerprinting by PCR).

Genes that are selected in the Southern Blot method are not very good candidates for the PCR method. One of the main reasons for this is that the Southern Blot system deals with very long strings of bases. The PCR method has a upper limit of a few kilobases long and many minisatellites are longer than that. For this reason PCR focuses on HLA genes or Major Histocompatibilty gene complex. The HLA genes are not just unknown "junk". These genes are the ones that are responsible for organ transplant rejection. Additionally HLA genes are associated with many autoimmune diseases. Examples of this would be insulin-dependant diabetes, multiple sclerosis and rheumatoid arthritis. Because of these two facts HLA genes are widely studied. This means that there are already meetings to share information, nomenclature and procedures for identifying and assessing variation. These genes are also extremely varied. There are at least 6 different genes that are highly variable in the HLA gene complex which have from 11 to 57 known variants. Since each person has two sets of these

genes there are at least 240,000,000,000 possible HLA genotype combinations (DNA Fingerprinting by PCR).

After duplicating a segment of DNA using PCR methods, variations can be located and identified in two general ways. First by identifying restriction sites specific to different variants and then digesting the PCR product with restriction enzymes that produce different restriction fragments that can be separated using electrophoresis and then visualized using fluorescent staining. A more direct method would be to simply determine the sequence of the PCR amplified variants. This approach is both more direct and it allows scientists to also locate previously undiscovered variations (DNA Fingerprinting by PCR).

Chapter-2: DNA Forensics

The field of Forensic Science is always changing. The main reason for this is that people will always commit crimes and there is still no perfect way to figure out who committed the crime so that they can be punished. The newest and arguably the best development in forensic science is the area of DNA fingerprinting.

DNA fingerprinting is the method that allows scientists to compare DNA from two different sources to see if it matches. DNA fingerprinting has two main uses. The first is that it works great for paternity testing. This is because children inherit half of their genetic information from each parent. This allows scientists to notice the similarities between both presumed parents and the child's DNA to find a match. The other use for DNA fingerprinting, which this paper will focus on, is the process where genetic information found at a crime scene is matched against the DNA of a set of suspects to try and pin guilt on one person due to the existence of their DNA at the crime scene. Over the last fifteen years there have been many strides in the field of DNA fingerprinting so that now a DNA fingerprint can prove conclusively that a person has was at a crime scene if no more than one of his cells was found there.

Why is DNA fingerprinting such a breakthrough for forensics? The main reason is that DNA is one of the things that a person who perpetrates a crime cannot change. A criminal could easily commit a crime and then change his name, face, hair color, body shape, fingerprints, and even gender if he felt so inclined. There is no way that a criminal can change his DNA. With a method to find such immutable proof that a perpetrator was at a

crime scene it is very important that the technology is very dependable so that errors will not result in horribly unjust rulings.

It is interesting to note that at this time the technology behind DNA fingerprinting has finally evolved to where the general public is aware of it, and court rulings based on its proper usage appear to be just and correct. If this is so, then why do we still see cases where there is doubt about DNA evidence in specific trials? The reason for this is that just because a technology can and should work correctly does not mean that there are not other factors that have to be dealt with. For example in the O.J. Simpson case multiple crime scene samples linked O.J. with the crime scene, but due to questions about whether police procedures concerning the evidence were followed in the correct manner threw a shadow over the DNA evidence.

After this highly publicized event, police departments realized that merely obtaining a match between a suspect and a crime scene sample is not enough to get a conviction in court. The department also has to follow an extremely strict regiment to make sure that their samples are pure and uncontaminated. When it comes to this issue there are four different questions that have to be asked. These questions are: how to get evidence accepted in court, what recently learned information is important to forensics, what evidence at a crime scene likely has DNA and what are the best ways to store DNA evidence.

Court Acceptance of DNA Fingerprinting

When it comes to DNA in the courtroom the first question is. Why do people want it there in the first place? DNA evidence can be used for both the prosecution and the defense. The prosecution can use DNA evidence to either put more credit in the fact that a suspect was

at a crime scene, or they can sometimes locate a suspect from a sampling of DNA compared to a DNA database. The defense often uses DNA evidence to exonerate wrongly accused people. In cases where DNA evidence is not presented at the time of the trial it can sometimes be used to overturn a verdict after someone has already been sentenced for a crime (Forensic Science and Genetic Variation, 2002).

In general if DNA from a crime site matches that of a suspect, which means that there is only one of two outcomes. Either the suspect was present at the crime scene or there was a coincidence. This may seem simplistic and even silly but it is actually an important factor. One of the main defenses against DNA data is the idea that that a match can be obtained by a chance. The reason that there is debate to this end is because a DNA fingerprinting case could focus on certain patterns that are more prevalent in a population and thus allowing for more people to match it. This is made even more difficult by the fact that many ethnic populations exhibit similarities in their genetic populations. This means that the system that would be used for one ethnicity may not be the best way to locate an individual in another one (DNA Evidence, when properly, 1996).

In general it used to be true that a very complicated formula would be necessary to determine the probability that a person of a particular ethnicity is a coincidental match. At the present time this process has been simplified. The reason that it can be simplified is that as DNA fingerprinting methods have become more widespread, more cases of different ethnicities have been examined to the point that scientists now know how to deal with DNA evidence from different ethnicities and do not have to apply a large difficult general formula to find out coincidental probability. Instead they can focus on a database of that ethnicity and construct the probability using only that information (DNA Evidence, when properly, 1996).

It cannot be argued that DNA is always 100% sure, but how often are other methods always right? There is a very slim chance that a DNA profile set will turn up in someone else who matches the DNA profile. On the other hand experts point out that DNA forensics is far superior to eyewitness accounts. In an eyewitness account the odds of a correct identification are about 50:50 (DNA Forensics, 2002). One movement called the Innocence Project works to overturn erroneous rulings. So far in 75% of cases investigated by the Innocence Project, DNA evidence was reported lost or stolen. Once DNA evidence surfaced for these cases half of the inmates were found innocent. In an examination of 70 wrong convictions 84% of them had mistaken eyewitness testimony, 23% had wrong confessions, 33% had junk forensic information (ex. microscopic hair comparisons), 50% had police misconduct, and 42% had prosecutorial misconduct (How DNA Technology Is Reshaping, 2001). This makes a pretty strong argument that DNA evidence can and should play a large role in an investigation because all of the 'normal' methods of investigation are very prone to mistakes. For this reason it is then very important to find out all of the new information about DNA forensics.

Recently Learned Forensics Information

DNA forensics cases at this time have learned one very important thing. This is that they have to make very sure that they do not mess up and contaminate or otherwise mislabel any of their DNA data. In an interview with DNA forensics authority Dr. Bruce Weir he was asked if he felt that human error in laboratories was the weakest link in DNA forensics. His response was:

> There has been a lot of discussion about the potential for human error. I would think the weak link would be right at the beginning, for example, does the tube labeled 'crime scene blood stain' reflect the true source of that material? The forensic laboratories have a lot of safeguards built in, such as dual observation

> of each step, and signing for custody of the evidence. Forensic laboratories have a lot of experience in taking care of evidence. But I take your point, if there is going to be an error, it would be of the gross human kind, rather than in technique. (An Interview with DNA Forensics Authority Dr. Bruce Weir, 2000)

This seems to indicate that in his opinion the DNA technique is not the part of the process that needs to be worried about. Instead it is the way that evidence is collected and tagged and 'gross human error' within the lab.

A prime example of these concerns happened to Lazaro Sotolusson in Las Vegas. When Lazaro Sotolusson was in custody in Las Vegas he was required to have a DNA profile. When his data was in the police crime lab his name was put onto the wrong DNA profile. After this happened, Sotolusson was charged with at least two rapes. Although defense lawyers finally cleared Sotolusson of the charges when the clerical error was brought to light, it still showed a disturbing mistake in the Las Vegas police department's crime lab. The mistake was not caught by any of the crime labs safeguards. The DNA profile was reviewed twice, each time by a different police lab employee, and neither of them caught the mistake.

This gross mistake prompted the department to propose a series of changes to prevent this from occurring again. These changes will include requirements that each DNA test be closely scrutinized for paperwork or transcript errors. This will change from the current situation where DNA tests are examined mainly to see if there were scientific errors in the tests themselves. A second safeguard will be a requirement of a second DNA test before a profile is entered to a computer database to try and match it with unsolved crimes. Finally the crime lab is exploring methods to automate the transcription process to cut out the human error inherent in data entry. After the error was realized, the police ordered every test

performed by the crime lab to be redone to see if anymore mistakes slipped through the cracks (Puit, 2002).

Knowing what problems may be present in the processing of DNA evidence is very important, but without methods to collect DNA from a crime scene these methods will be left unused. For that reason it is very important to know where DNA evidence is usually found, what kinds of tissue leaves DNA evidence that can be used in a criminal investigation and how to handle each kind of DNA evidence.

What at a Crime Scene Contains DNA

It may sound like a simple question but there are many different things at a crime scene that can contain DNA from different sources. For this reason it is very important that a detective at a crime scene knows what to examine and how to collect and process different materials. The list of useful things at a crime scene is quite extensive: mucus, blood, sweat, semen, skin, tissue, hair, dandruff, saliva, bone, and teeth are all useful samples to be collected from a crime scene. Less useful samples would be feces or urine, biological samples that were contaminated with soil and samples from certain substrates like jeans or denim, which have been known to mess up DNA analysis (DNA Evidence Collection Principles). Urine samples should routinely be obtained, although in general a healthy person's urine will not contain any cells that can be used for DNA analysis. Urine may contain epithelial cells. These cells do contain DNA and can be used in DNA testing. The bad part is that a healthy person should not have epithelial cells in their urine (DNA Forensics Problem Set 2, 1997).

Before collecting samples of different kinds it is important to know exactly how much of each thing is the standard amount. Blood is an excellent source of DNA. Red blood cells are not used in DNA testing because they have no nuclei, and thus no nuclear DNA. White blood cells on the other hand are great for DNA testing because they contain nuclei unlike red blood cells. To be able to do a DNA profile all that is necessary is a 50 ul volume of blood, which turns out to be about a dime sized bloodstain. Semen is often the best source of DNA information in sexual assault cases. The heads of the sperm contain all the genetic information necessary to run a DNA test. A DNA test can be run on a sample of semen that is just as large as a blood sample (Forensics Problem Set 2, 1997). For urine or saliva it is important to collect a large quantity to make sure that testing can take place. One to two cubic inches of red skeletal muscle should be collected, three to five inches of long bone should be collected. As for teeth they should be collected from nonrestored molars first which are more likely to contain pulp. In taking a hair sample it is important that you collect plucked hairs because hair that has just fallen out does not contain DNA (Handbook of Forensic Services, 1999).

Armed with the knowledge of DNA evidence, and how much of it is necessary, it is just a matter of finding those items. Weapons like baseball bats can contain DNA on either the handle or the end and may contain sweat, skin, blood or tissue. Hats or masks can contain DNA on the inside and they may have sweat, hair, or dandruff. Glasses would have DNA on the nose, ear pieces or lens and may contain sweat or skin. Tissues, dirty laundry, blankets, pillows or sheets would have DNA on their surface area and could contain mucus, blood, sweat, or semen. Toothpicks, or cigarettes may have saliva on their ends. Stamps and envelopes can contain saliva. Bottles, cans or glasses may contain saliva or sweat on their

sides or mouthpieces. Used condoms would have DNA on their insides or outsides and can contain semen, vaginal or rectal cells. Bite marks on skin or clothing can contain saliva. Finally fingernails can contain blood, sweat, or tissue (What Every Law Enforcement Officer, 1999).

There are a few ways to collect samples from a crime scene. There are a lot of different situations where blood can be collected. Wet blood can be found on a person, surfaces, or on snow or water. In these cases it is best to pick them up with a clean cotton cloth or swab making sure to leave an area unstained as a control. Air dry the sample and then pack it in clean paper or an envelope with sealed corners. Dried blood on people or immovable objects should be absorbed onto a cloth or swab after wetting the cloth with distilled water. After absorbing the blood the cloth should be dried and stored in a paper envelope. When possible cut a large sample of a bloodstain off of a bloodstained immovable object for testing (Handbook of Forensic Services, 1999).

Semen collection is very similar in nature to blood collection. Liquid semen should be absorbed onto a cloth or swab, dried and packed in clean paper. Objects with dried semen on them should have a large sample of the stained section cut and packaged in clean paper to be delivered to the lab. Seminal evidence from sexual assault victims should be refrigerated and submitted as soon as possible to the laboratory (Handbook of Forensic Services, 1999).

Saliva and urine should be handled like semen in the cases of liquid saliva or urine, and when dry saliva or urine is suspected on objects. Cigarette butts should be picked up and dried and sealed in a dry envelope. Ash and ashtrays should not be submitted unless

ashtrays are being fingerprinted. Envelopes and stamps should be removed with clean forceps and sealed in a clean envelope (Handbook of Forensic Services, 1999).

Hair should be picked up carefully with clean forceps to prevent damaging the root. Hair that is mixed with suspected body fluids should be air dried. All hair groups should be packaged separately in clean paper or envelopes and should be refrigerated and submitted to the lab as soon as possible (Handbook of Forensic Services, 1999).

Because small amounts of DNA can be used as evidence it is very important to make sure that DNA is uncontaminated. This means that people should not sneeze or cough over evidence, or touch their face and then touch an area that may contain DNA evidence. To reduce the risks of contamination it is important to always wear gloves and change them often, use disposable instruments or clean them thoroughly before and after handling each sample, avoid touching the area you believe DNA may exist, avoid talking, sneezing, and coughing over the evidence, avoid touching your face when collecting and packaging evidence, air-dry evidence thoroughly before packaging and put evidence into new paper bags or envelopes not plastic bags (What Every Law Enforcement Officer, 1999).

When transporting or storing DNA it is important that the evidence is dry, at room temperature, and is sealed in paper bags. Never place evidence in plastic bags because they will retain moisture that will damage DNA evidence. It is also important to know that warm conditions and direct sunlight is also harmful to DNA evidence so it should not be put in places that may get hot (What Every Law Enforcement Officer, 1999).

Chapter-3: Landmark DNA Court Cases

In the American legal system, a defendant is brought to trial and is judged by a jury of his or her fellow Americans. During trial, evidence is brought forth by the defendant's counsel and by the prosecutor. The jurors then make their decision based upon their interpretation of the evidence, the application of their own reasoning, logic and judgment. The key point in this procedure regarding DNA is how (and whether) evidence is brought forth, and how it us used to logically and reasonably prove a point.

Frye v U.S., 1923

The original standard for determining whether a scientific method or principle would be accepted or denied by the court was derived from the case of *Frye v. US, 1923*. In this case, the defendant, James Alfonso Frye was subjected to a "lie detector test", also known as a systolic blood pressure deception test, in an attempt to determine if he was guilty of murder in the second degree. It was scientifically established that systolic blood pressure is influenced by a person's emotions, and that changes in this blood pressure are due to nervous impulses sent to the nervous system. Using this theory and various scientific experiments, scientists concluded (incorrectly as we now know) that conscious deception, fear, or a sense of guilt would produce a sudden change in systolic blood pressure that could easily be detected when asking a suspect a series of questions (Green et al, 2003). Frye did in fact pass the lie detector test.

Frye's lawyer attempted to call forth the scientist who conducted this lie detector test, as an expert witness to testify before the court. However, the government's counsel objected to such a witness, stating the following:

"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 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." - Court of Appeals for the District of Columbia, 1923 (Appeals – Frye, 1923)

The government's counsel continued on to say that the systolic blood pressure deception test had not yet gained recognition or acceptance in the fields of psychology and physiology, such fields where the test would reside in. The counsel believed that if such a test was accepted by the professionals and experts of such fields that it would warrant the admission of such expert testimony regarding said test. The court sustained the objection, recognizing the importance of a technique having general acceptance in a particular field before allowing it in the courtroom.

The resulting effect of the 1923 Frye case was a legal precedence regarding the admission of scientific evidence in a courtroom. Future courts would use the Frye case and the notion of "general acceptance" within the scientific community for a relevant technique to be accepted in a court of law. Before a scientific method or principle was accepted in a court of law, it had to be well established and agreed as valid within the particular field of science or study that it originated from.

Often in a legal proceeding there is a need for specified, focused knowledge in a particular field or subject. This knowledge can be complex or require a lengthy amount of background knowledge and learning for it to be comprehended. A judge and jury will have

neither the necessary background education in such a topic nor will they have the time to sit down and examine research papers during a trial. Therefore it is often necessary to call in an individual that has studied the subject in question to some great depth. This is known as an expert witness.

Federal Rules of Evidence, 1975 (Rule 702)

After many years of using the Frye test in courts, it became apparent that it was difficult to establish "general acceptance" in the scientific community, so in 1975 a different rule was established. In an attempt at providing more tolerant guidelines for scientific-evidence submission than the Frye standard allowed, the Federal Rules of Evidence were passed in 1975 (Green et al, 2003). These Rules of Evidence redefined testimonial submission, context and constraints, as well as evidence submission and acceptability.

Within the Federal Rules of Evidence was a rule, Rule 702, that not only allowed for an expert witness to testify upon specified knowledge, but the testimony must be based on reliable scientific methods (not necessarily generally accepted), and the methods must have been applied correctly. This became the new standard for accepting scientific knowledge in a court of law.

> *"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, Testimony by Experts, as amended effective December 1, 2000.

The Frye standard allowed a scientific method to be thoroughly reviewed and critiqued by men and women within the particular field associated with such a method or science. Rule 702 also provides for expert testimony, but side steps the Frye standard to an extent and allows for a far more flexible submission of a scientific method into evidence. Under Rule 702 someone who is qualified to be an expert in a particular field, due to their extensive learning or experience, can give expert testimony on a subject relative to their experience or learning. As mentioned in Rule 702, the witness may testify "based upon sufficient facts or data". The witness must also support what he or she states using reliable methods or principles. The witness must also apply these aforementioned reliable methods or principles in an appropriate and reliable manner.

There is vagueness as to what is considered "reliable". In the Frye v. US case, the precedent was set that scientific methods should be generally accepted by the scientific community where as here, in Rule 702, it simply states that the scientific method or principle should be *reliable*. The question then becomes what *is reliable* and *what is not reliable*. The presiding judge decides what shall and shall not be considered reliable, and therefore shall decide what is and is not admissible. The court judge assumes the role of a "gatekeeper"; the judge opens the gate to allow a testimony in or to bar it from evidence (Green, Murry, and Nesson - Rule 702, 2003).

With Rule 702 a witness that has been deemed qualified as an expert in a particular field, may be called to testify on a particular subject. The expert witness will be used to assist the court in understanding or comprehending that which could normally take years of studying to grasp.

When the Federal Rules of Evidence were first established the legal community did not immediately embrace them with open arms. The Federal Rules of Evidence conflicted with the very well established Frye standard that many courts had been relying on as a guideline. That reluctance quickly changed with the case of Daubert v Merrell Dow Pharmaceuticals.

US v Downing, 1985

DNA forensics and fingerprinting have become a versatile and commonly accepted tool in the legal system, though it was not always so. When DNA first appeared as a tool for the legal system to prosecute criminals, there was great skepticism. It had not yet become a widely accepted scientific method in the scientific community and was turned down by some courts still using the Frye standard for scientific evidence.

In 1985, John W. Downing was charged with wire fraud, mail fraud and interstate transportation of stolen property. Downing was attempting to defraud numerous vendors while working with a group of individuals calling themselves the Universal League of Clergy or U.L.C. The government's case against Downing involved calling upon twelve eyewitnesses to identify Downing as the man the witnesses knew as Reverend Claymore. Downing's counsel inquired if the court was going to allow expert testimony on the "unreliability of eyewitness testimony".

Downing's counsel argued that eyewitnesses were incorrect with their testimony and that their testimony was unreliable. The basis for this assessment was *"because of the short period of time in which the witnesses had to view Claymore, the innocuous circumstances of*

their meetings with him, and the substantial lapse of time between the meetings and the subsequent identifications." (Green, Murry, and Nesson – Downing, 2003)

Downing's counsel attempted to call forth a psychologist as an expert witness in an attempt to confirm the previously stated belief that eyewitnesses were unreliable in their testimony. The court denied the psychologist as an expert witness based on belief that the witness would commandeer the "function of the jury" and thus undermine the decision making process of the jury. The court also stated, though later found to be false, that there was additional evidence "such as fingerprints [and] handwriting." The main point being that calling a psychologist would undermine the ability of the jury to judge the validity of twelve eyewitnesses. Under Rule 702 some testimony can be rejected because it commandeers the territory granted to a jury in the decision making process. The case went to the jury without the expert's testimony and the appellant (Downing) was convicted. Downing appealed his case.

> *"For example, in State v. Chapple, 135 Ariz. 281, 660 P.2d 1208 (1983) (applying Arizona's version of the Federal Rules of Evidence), the Supreme Court of Arizona set aside a jury's guilty verdict and ordered a new trial on the ground that the trial court had erroneously excluded an expert on eyewitness identification offered by the defendant. In addressing the question whether the expert's testimony would have been "helpful" to the jury in reaching an informed decision, the court noted several specific factual "variables" that were present in that case which, the defendant's expert was prepared to testify, reduced the eyewitnesses' ability to perceive and remember accurately."* (Green, Murry, and Nesson – Downing, 2003)

The court began to review previous cases and standards like the Frye standard and the Rules of Evidence (particularly Rule 702). The court concluded that scientific principles that

could aid the trier of facts can be admissible, even though they have yet to come under review by peers. The court also concluded that some scientific evidence could very well confuse the jury and subsequently blur their judgment, so the judge can deem such evidence non-admissible.

The court then brought forth the helpfulness standard in regards to expert testimony, the stipulation that the testimony must be sufficiently tied to the facts of the case, and that the testimony will help the jury in reaching a verdict before it is allowed [in the courtroom]. Using these three points from Rule 702 in the Rules of Evidence, the court stated that Downing's counsel must make a detailed explanation as to how the expert's testimony would be relevant to the eyewitness testimony regarding the identification of Downing. The court then delayed judgment so a district court could determine the relevancy of Downing's expert witness.

In regards to Downing's appeal, the court found that the expert testimony to be offered was not reliable enough to warrant admission into evidence. The court upheld the previous sentence regarding Downing; guilty of all charges except interstate trafficking (Green, Murry, and Nesson – us-v-do2, 2003).

Andrews v Florida, 1988

In 1988 the first case occurred in which DNA evidence passed uncontested into evidence, demonstrating that by that date DNA forensics had become a well-known subject and was thoroughly accepted in the scientific community. In 1988, a Florida man by the name of Tommy Lee Andrews was convicted of rape. Forensic scientists examined traces of semen found in a rape victim and tested them against Andrews' DNA samples.

"A scientist from Lifecodes and a MIT biologist testified that semen from the victim matched Andrews' DNA, and that Andrews' print would be found in only 1 in 10 billion individuals." (Coleman, 1994). Defense counsel did not challenge these witnesses nor did they provide examination that questioned the scientific acceptance or reliability of DNA testing. The jury returned a verdict of guilty, and Andrews was sentenced to 22 years imprisonment by the Circuit Court in Orange County, Florida.

It should be noted that in this trial at no point was the subject of DNA testing or DNA forensics an issue, nor was it contested. This case clearly exemplifies the acceptance of DNA fingerprinting in legal and scientific communities. *"This was the first criminal case in the United States in which DNA was used. The court accepted that the scientific method which was used complied with the famous test in Frye v United States 293 F 1013 9DC CIR 1923."* (Olivier, 2001).

Ohio v. Pierce, 1988

In the same year as the Andrew's trial, in Delaware State Park, Louis Pierce, Jr committed numerous crimes ranging from several rapes, to aggravated robbery, and kidnapping. Rape kits were performed on the victims to collect DNA samples of the culprit that were later presented before the court as evidence.

The defendant objected to such DNA samples being admitted into evidence on the grounds that such documents and information had not been made available to the defendant as is required by law. When provided with the information, the defendant's counsel objected yet again to the admission of DNA evidence. In a later hearing regarding the objection, Pierce's counsel argued that the community had not accepted such forensic methods. Pierce's counsel

went on to argue that no standards regarding the testing of DNA samples for forensic purposes had been set and therefore the DNA analysis was unreliable. The judge decided to allow the jury to determine the reliability of the analysis, and Pierce was subsequently found guilty on all counts accept aggravated robbery (Reporter - State of Ohio, 1992). Thus this case further demonstrates the positive tone concerning DNA testing in 1988. This positive attitude was about to change in 1989.

People v Castro, 1989

Science never boasts to be an exact art. Science is a never-ending attempt to explain what occurs in the world(s) around us. Science is continually renewing and changing what was previously assumed to be valid and true. In the case of People v. Castro, the science behind DNA fingerprinting got a taste of such renewal and change.

On February 5, 1987 a woman and her two-year-old daughter were stabbed and killed in the Bronx. When police began their investigation and questioning, it was discovered that a local man by the name of Jose Castro had blood on his wristwatch. Samples of the blood were sent to the Lifecodes laboratory to be tested and analyzed against the blood and DNA samples of the victims. The analysis reported that the two samples, from the victims and from the wristwatch, were a match with no unusual discrepancies or errors in the analysis process. Prosecution attempted to have these results entered into evidence.

A 12-week pretrial hearing occurred in which numerous points regarding the admissibility of DNA evidence were examined. This pre-trial hearing proved to be the most detailed critique of DNA evidence performed at that time. On August 14, 1989 the court reached a decision in which the DNA samples were not allowed into evidence. As a result,

Jose Castro was released and free of charge. Although the court concluded that DNA forensic tests had become an accepted and useful scientific method, the court ruled that the specific tests performed by Lifecodes were not reliable. The court also noted that there should be some standard for determining if a DNA analysis was performed accurately and with precision. The court developed a three-prong test to determine if DNA evidence was accurately assessed and subsequently admissible in a court of law:

> *Prong 1:* Is there a theory that is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results?
> *Prong 2:* *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?
> *Prong 3:* Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case?

With regards to the case of People v. Castro, the court concluded that DNA was unique to each individual and henceforth not possible to fake, replicate or manufacture (prong-1, generally accepted theory). The court also concluded that DNA analysis could be used to compare two samples and form a probability of match (prong-2, currently existing techniques). But the evidence failed prong-3: the court concluded that although the tests and analyses that Lifecodes had performed were capable of producing reliable results, here the tests were not performed correctly. They concluded that Lifecodes did not perform the accepted scientific techniques in analyzing the forensic samples, and did not apply appropriate, approved procedures in their testing. Thus the DNA evidence was not allowed. The case actually never went to trial, Castro pled guilty. The end result of the Castro case

was that it signaled an end to the "blind" acceptance of DNA fingerprinting in U.S. courts, and formulated a famous 3 prong test for allowing technical tests in courts.

Minnesota v Schwartz, 1989

In further establishment of DNA analysis standards for forensic laboratories, the Supreme Court of Minnesota, in the case of *State v. Schwartz,* rejected the use of DNA evidence analyzed by a specific forensic laboratory. This was the first occurrence of an appellate court doing such. Based on the results of *People v. Castro*, the Minnesota Supreme Court overturned DNA evidence in *State v Schwartz* due to the forensic laboratory's failure to comply *"with appropriate standards and controls and on the availability of its testing data and results."* (CLS, 1992).

An issue that arose was the failure of the laboratory to reveal the population data and testing methods used in the analysis. The court held that the reliability of a test implies that it could be subjected to an independent assessment of the testing procedure. The testing laboratory was also guilty of falsely identifying two samples as coming from the sample subject during a proficiency test. Due to the secrecy of the laboratory, such an assessment of the methods used by the laboratory never took place, and in addition to the falsely identified samples, the court subsequently believed that the evidence was inadmissible. The case of *State v. Schwartz* is a prime example for the need of DNA analysis standards in the legal system.

After this court case, the Federal Bureau of Investigation (FBI) created the standards for DNA analysis, forming an interagency group known as "The Technical Working Group on DNA Analysis Methods" (TWGDAM) (TWGDAM, 2003). It was this group that

established the standards for DNA analysis and testing in the field of DNA forensics and fingerprinting. Once the standards for DNA testing had been establish, a testing laboratory simply needed to follow the standard procedure.

Daubert v Merrell Dow Pharmaceuticals, 1993

In the case of Daubert v Merrell Dow Pharmaceuticals, two children, Jason Daubert and Eric Schuller, were both born with birth defects. Their pregnant mothers had taken a prescription anti-nausea drug called Bendectin, marketed by Merrell Dow Pharmaceuticals. The parents of the children came forward to sue Merrell Dow Pharmaceuticals, and were met by expert witnesses giving testimony that Bendectin does not cause birth defects, contrary to what the parents were attempting to establish. The parents followed by bringing forth their own expert witnesses.

The parents and their legal representation undertook their own analyses of the Bendectin studies regarding human malformations. Their studies and recalculation of previous data showed that Bendectin was in fact capable of causing human birth defects. However, since the recalculations had not been published and presented before the scientific community, the court did not allow the recalculations into evidence. The court felt that because the reanalysis did not undergo scrutiny and examination by peers it was not admissible into court as scientific evidence. This decision was clearly rooted in the Frye standard. Subsequently, Merrell Dow Pharmaceuticals Inc. was found not guilty.

The case was appealed by the families and it ended in a verdict of not guilty for Merrell Dow. When the case was brought before the Supreme Court, the families argued that the Frye standard was outdated by the adoption of the Federal Rules of Evidence. They

believed that the Rules of Evidence held more authority than the Frye test. They began to argue a new perspective regarding the Rules of Evidence. Their resulting argument caused a change in the perception of what is relevant and acceptable as evidence in the courtroom.

> *"In its Daubert opinion, the Court recognized that general acceptance by the scientific community was a relevant factor in determining the admissibility of expert testimony based on a scientific theory or technique. Id. at ----, 113 S.Ct. at 2797. But such acceptance, the essential ingredient of the Frye principle, is not the sole test. Id. Peer review and publication of the theory or process is pertinent but also not an indispensable predecessor of admissibility. Id. [641 N.E.2d 1349] at ----, 113 S.Ct. at 2797."* (Johnson, 2000)

The above passage states that although the Frye standard can be a determining factor in the admissibility of an expert testimony based on a scientific principle, it is *not* the only method through which acceptance can be obtained, as argued by Daubert. Under Rule 702, admissibility is redefined by whether or not an expert testimony based on scientific knowledge is helpful or useful.

Subsequently, in order to determine if expert testimony will be relevant, a preliminary assessment of the reasoning or methodology underlying the testimony must be taken. The judge must also examine if whether that reasoning or methodology can be properly applied to the issue at hand. Once this is executed, the testimony of an expert witness, regarding a particular scientific subject of principle, is for the most part (unless proven otherwise) considered to be valid and truthful (Daley and Thomas, 1999).

The court believed that the main goal of the Rules of Evidence was to establish reliable expert testimony, the same purpose that the Frye standard was created for. Under the Rules of Evidence, the judge now becomes the gatekeeper for what is admissible, and in the

case of Daubert v. Merrell Dow Pharmaceutical, Inc. the Supreme Court effectively established the authority that the Rules of Evidence had over the Frye standard for entering evidence (Daley and Thomas, 1999). The Supreme Court vacated the Appellate Court's ruling and ordered the case to proceed in the District Court with the new established guidelines. The case is still pending.

Chapter-4: Sensational DNA Court Cases

Thomas Jefferson and Sally Hemings

During the Presidential scandal involving President Clinton and an intern, a DNA analysis report was rushed into the public's hands citing that former President Thomas Jefferson fathered children with a slave. In today's society, an interracial relationship is commonplace and generally accepted in society. However, during the time of Thomas Jefferson, during the late 1700's and early 1800's, such relationships were unacceptable in society. Of course, DNA testing was not around at that time to prove beyond a reasonable doubt whether Jefferson fathered a child with a slave.

Historians have long debated the rumor that Jefferson had fathered a child with one of his slaves, Sally Hemings. In 1802, allegations regarding Jefferson and his slave were made while Jefferson was President of the United States.

Recently, scientists gathered as much DNA from the descendants of the Hemings and Jefferson lineages for DNA analysis and comparison. A study published reported that there was a match in the Y-chromosome between the descendants. The Y chromosome DNA is passed from father to son and rarely changes or mutates over the course of several generations. A male lineage can be distinguished from another male lineage through the particular DNA characteristics or the specific mutations carried in that lineage's Y-chromosomes. The study tested the descendants of Heming's last son, Eston Hemings, and of Jefferson's paternal uncle, Field Jefferson (Smith and Wade, 1998).

The testing was performed at the University of Oxford in England. It was discovered that the Y-chromosome specific to the Jefferson lineage had a distinct mutation. 1,200 men,

mostly European, were analyzed by the same method and none had a matching DNA mutation in the Y-chromosome. It was estimated that there was less than a one-percent chance that a random person would have a Y-chromosome that matched the Jeffersonian chromosome (Smith and Wade, 1998).

Critics of the test argue that, because the testing was rushed to be publicized, the public was misinformed as to the true meaning of the testing results. Critics argue that the testing proves that a Jefferson fathered the children of Sally Hemings; the testing cannot and does not specify which male Jefferson.

In a news conference, Dr. Eugene Foster, a retired Virginia pathologist and the leading author of the DNA study, defended the conclusion regarding Jefferson.

> "From the historical knowledge we have, we cannot conclude that ... any other member of the Jefferson family was as likely as Thomas Jefferson to have fathered Eston Hemings."
> {Ishipress-drfoster, 1999}

No DNA samples were taken from Thomas Jefferson's remains. There is also no way for modern scientists to obtain such a DNA sample for testing, therefore, the question regarding Jefferson and Hemings can never completely be answered, it can only be left to further speculation and debate.

Anastasia

One of the more controversial Russian folktales and legends is the story of Anastasia, the youngest daughter of Tsar Nicholas II of Russia. The Romanov dynasty ended in 1917 with the uprising of the Bolsheviks. Nicholas II and his family, who were Romanov, fled west to Germany to stay with relatives. They were captured by Bolshevik revolutionaries, and on

July 16th were executed by a Bolshevik firing squad in Yekaterinburg, Russia. The enduring legend was that Anastasia was spared the firing squad, and was alive.

In 1991, President Boris Yeltsin authorized the excavation of Yekaterinburg, the assumed site of the execution. Of the bones found and reconstructed, it was established that two of the skeletons indeed were not present. A British forensic scientist, Peter Gill, "performed nuclear and mitochondrial (mt) DNA tests on the nine bone samples. Five of the bodies were clearly related, and three were female siblings." {Editorial, 1996}. The three female siblings were quite possibly Anastasia's sisters.

Rumor had it that when the soldiers fired upon the royal family of Nicolas II, bullets ricocheted off of jewels hidden in the corsets of the young duchesses. The family had planned on sneaking the jewels out in order to buy their way across country to Germany and to reestablish their lives on foreign soil. The royal family did not reach their destination {Editorial, 1996}.

In February 1920, a young woman was rescued from the Landwher canal after having jumped from the Bendler Bridge in Berlin, Germany. This woman refused to speak to local law enforcement agents, and was subsequently sent to an asylum in Dalldorf. Her roommate, Clara, began to mistakenly suspect that the unknown woman was actually Nicholas II daughter, Anastasia.

Upon Clara's release, she sought out the attention of Russian monarchy living in Germany {Tsarskoe, 1999}. "Anastasia" began to speak of what happened to her family, speaking only in fragments and was never entirely coherent. "Anastasia" spoke of how soldiers shot her family in the basement of a Russian home, and spoke of detailed information that had been kept hidden from the public's knowledge. She claimed she had been bayoneted

and left for dead, and that she later woke to find herself in a wagon, rescued by one of the guards that realized she was still alive. When the wagon finally reached German soil, "Anastasia" and her companions were separated. It was then, that "Anastasia" threw herself off the bridge, into the canal, most likely in despair or grief.

Russian monarchy and aristocrats in Germany began to believe that this woman was indeed the lost Anastasia. There were uncanny similarities between this woman and the former Anastasia; they had the same height, hair color, eye color, childhood scar, and the same identical foot deformation.

In 1984, "Anastasia" passed away in the US, and was cremated, as she desired. The only DNA samples available for DNA testing were a drop of blood on a slide in Germany, a tissue sample and a strand of hair. The tissue and hair samples matched one another, and surprisingly they also matched the blood of a missing Polish factory worker, Franziska Shantkovska (known as Anna Anderson in the US), a commoner. Many historians now believe that Anna Anderson was in actuality the missing Franziska, not Anastasia, the Duchess of Russia.

Peter Kurth, a well-known researcher on the Anna Anderson-Anastasia controversy has written extensively on the belief that Anna Anderson is in fact the lost Anastasia.

> *"I quote Brien Horan, who introduced me to Anna Anderson in July 1973: I knew her well and therefore have formed a personal opinion in her favor. I cannot dispute DNA findings and I am not a conspiracy theorist. But I cannot suspend everything I know on the basis of these tests. … The odds are long that a fake claimant would be the right height, eye color and hair color, to begin with. The hallux valgus* [foot deformation] *is an even greater long shot. The handwriting match is mind-boggling. And the ears send the odds right out of the park."* {Tsarskoe, 1999}

Although the DNA testing concluded that Anna Anderson was directly related to the common Polish workers (of which Anastasia would have had absolutely no relationship or

kinship to) there are still many that believe Anna is Anastasia. Their steadfast belief is rooted in the accumulated non-DNA evidence, the massive similarities whose coincidences seem far too improbable. Though DNA testing has been performed, there is still a certain belief in the minds of many that Anna Anderson was Anastasia, and the legend will most likely propagate itself into the minds of future generations.

The Boston Strangler

The case of the Boston Strangler is perhaps the most infamous serial killing in the state of Massachusetts. Between the years of 1962 to 1964, an unknown serial killer struck the Boston region, brutally raping and killing eleven young women. The killer managed his way into numerous apartments and houses of young women either through his charm, apparent innocence or through trickery. There was however no sign of forcible entry. The killer then proceeded to strangle the young women with clothing and then sexually molest them.

In 1965, a blue-collar factory worker named Albert DeSalvo confessed to being the individual responsible for the eleven official murders associated with the Boston Strangler. DeSalvo had a history of burglaries and brushes with the law. Albert DeSalvo had a wife and son, and was the "bread-winner" in the household, falling on hard times.

When the interrogations began, DeSalvo provided detailed information about the murders; information that had not been released to the general public and information that only someone standing at the crime scene could obtain. DeSalvo began to graphically explain how he sexually molested and strangled the young women with their garments. His comments directly matched police records for all cases except that of victim Mary Sullivan.

In regards to Mary Sullivan, DeSalvo claimed that he left a knife and a sweater at the scene of the crime. This was not so. DeSalvo also claimed to have strangled Sullivan with his bare hands and to have raped her. This was also found to be untrue. A forensic scientist who took part in an autopsy arranged by the families said experts were unable to find the effects of a blow DeSalvo claimed to have inflicted on Sullivan. Despite inaccuracies and doubt in DeSalvo's confession, the public and legal system continues to believe the DeSalvo was in fact the Boston (Bardsley and Bell, 2002).

The night before DeSalvo was murdered in prison, DeSalvo telephoned a Dr. Ames Robey and asked to meet with him. To Dr. Robey, DeSalvo sounded frightened and there was a sense of urgency in his voice. DeSalvo told Robey that he also wanted a reporter present and that DeSalvo was going to "tell us who the Boston Strangler really was, and what the whole thing was about." The following night DeSalvo was killed (Bardsley and Bell, 2002).

Perhaps the truth regarding the identity of the Strangler died with DeSalvo, but science might be able to once again shed light on a dark situation. In October 2000, the DeSalvo family and the family of one of the victims, Mary Sullivan, joined to have Sullivan's remains exhumed for DNA analysis. Forensic scientists exhumed the body of Sullivan for DNA testing. On October 26, 2001, DeSalvo's body was exhumed in order to gather DNA samples. DNA analysis was performed on stains on her clothing and remains from two other individuals, and neither matched DeSalvo's DNA. This evidence can clear DeSalvo of the sexual assault charges for the assault on Sullivan. It does not necessarily clear him of the crime of Sullivan's murder, or any of the other 10 murders.

If DeSalvo did not rape Mary Sullivan, who did? Does this mean that DeSalvo was not the Boston Strangler as the public was led to believe? Many researchers believe that there were numerous stranglers, as the attacks, methods of attacking, ritual-ism and victims were all random in their respective natures; none of the victims or methods of attack matched any pattern which is typical of serial killings. Many others have argued that DeSalvo learned of the killings while he was in prison, especially from his cellmate Nash, who had previously been convicted of several rapes.

Regardless, DeSalvo was cleared of a crime that he confessed to committing. Tests are also being conducted on 68 samples of hair, semen and tissue taken from Sullivan's exhumed body. No evidence of DeSalvo was found at the scene of the crime. DeSalvo did however "confess" to Sullivan's murder and molestation. DNA testing and analysis, however, say otherwise. DeSalvo and his family were falling on hard times and *"The DeSalvo and Sullivan families believe DeSalvo may have confessed in hopes of making money from book and movie deals."* (Lavoie, 2001).

In October 2000, the DeSalvo and Sullivan families received little help from the Massachusetts Attorney General's office in their attempt to reopen the case regarding the slaying of Mary Sullivan. An order from a judge to resolve the issue was less than effective. Shortly thereafter, Attorney General Thomas Reilly stated that he would not be releasing any evidence regarding the Boston Strangler case. As a result, the DeSalvo and Sullivan families brought forth a previous lawsuit against the state in an attempt to have the evidence released so that the families can pursue their own investigation.

A private investigation led the families to evidence that did not indicate any signs of strangulation, thus convincing the families even more that DeSalvo was innocent. Should

further DNA evidence substantially prove that DeSalvo was innocent, without a doubt, the case could be reopened and the investigation continue.

California v. OJ Simpson, 1994

Orenthal James Simpson, better known as O.J. Simpson, is perhaps one of the more famous running backs in American football, both on the field and off the field. On June 12, 1994 Simpson's wife, Nicole Brown Simpson and Ronald Goldman, a waiter, were murdered in Nicole's condominium in Los Angeles.

On June 17, the day after the funeral of Nicole, police followed O.J. Simpson as his white bronco led helicopters, the media and the police on a wild chase. This was, however, just the beginning of a media sensation that brought the entire country to the television screen to watch the drama of what was labeled as "the trial of the century".

The Simpson-murder trial was perhaps the greatest circus to ever occur in a courtroom. Judge Lance Ito exercised little control over the lawyers, there were allegations and undertones of racist cops, evidence being planted, and there was testimony regarding the supposed ill performance of DNA analysis laboratories.

Phrases like "DNA analysis" and "DNA evidence" was dumped into the media for the public to digest. There was a large amount of evidence gathered at the home of Nicole Brown Simpson; in particular, drops of blood. The blood at the scene of the crime failed to match the victim's blood types. When Mr. Simpson's blood was drawn and tested, it was found to match the samples (about 0.5% of population would match). There were also traces of the blood of both victims lifted from inside Simpson's car and house, along with blood that contained his own DNA (Ramsland, 2003).

During the trial, prosecution brought evidence that indicated that blood found at the crime scene could have come from only 1 out of 170 million sources of blood. OJ was one that fit the criteria for those sources. Blood was also found on two black socks in O.J.'s bedroom. Testimony indicated that only 1 out of 6.8 billion sources of blood matched the sample (Linder, 2000). To counter such damaging evidence, the defense attempted to push the notion that the evidence had become contaminated or they were planted by corrupt police officers. However, the evidence had been analyzed before blood samples were drawn from Mr. Simpson. After the crime scene results were in from the lab, the DNA in Simpson's blood was analyzed and found to be a match to the blood at the crime scene.

Three different DNA laboratories performed the analysis and DNA testing on blood gathered from the crime scene. All three labs determined that the DNA in the blood matched Simpson's. It was a 1 in 170 million match, using one type of analysis known as RFLP, and 1 in 240 million match using the PCR test (Ramsland, 2003). Criminologist Dr. Henry Lee testified for the defense that there seemed to be a discrepancy with the way the blood was packaged. This was slightly vague in nature and description, but Dr. Henry Lee's polite and charming courtroom demeanor quickly won over the jury for the defense.

The defense began to argue that the samples had been tampered with or switched. Defense and prosecution experts then began to argue over whether the blood had been severely degraded from being stored in a lab truck. The defense then began to claim that the lab had mishandled all five-control samples, a claim that seems highly improbable (Linder, 2000).

DNA evidence and analysis was relatively new to the public during the Simpson murder case. The defense managed to explain DNA evidence and analysis in simple terms

whereas the prosecution went into in-depth and complex explanations. The jury was won over by the defense's explanation of DNA, as opposed to the difficult explanation that the prosecution was offering.

The O.J. Simpson case had 150 witnesses over 133 days, had cost $15 million and introduced the general public to "DNA evidence". It took the jury three hours to decide the verdict of the case: Orenthal James Simpson, better known as O.J. Simpson, was found not guilty on the charges of murder. This trial introduced the public to DNA testing in a sensational way, and in particular led to a more standardized protocol for performing the tests, and for preventing possible contamination. The defendant was subsequently convicted of murder in the follow-up civil trial, in which the legal standard moved from "without a doubt" to a more simple "preponderance of the evidence".

Chapter 5: National DNA Databases

Introduction

DNA evidence is fast becoming commonplace in the courtroom. Since DNA evidence was first used in 1986, its use in court has become more and more prevalent (Rodin, 2002). Today it is almost expected that most felony cases will have DNA evidence. Dr. Paul Ferrara, director of the Virginia Division of forensic Science, says "I think in the last 10 years DNA technology and its use in the courts has become so customary that if, in fact, DNA evidence is not presented, the judge or the jury is going to be saying, 'Where is the DNA?'" (Siegel, 2000).

DNA is the most powerful piece of forensic evidence that exists today. As DNA evidence appeared in the courtrooms more, the federal government quickly realized that they needed a way to best take full advantage of such a strong forensic tool. Eventually the idea of a national searchable DNA database was born.

Law Enforcement Databases

In 1990 the FBI founded the Combined DNA Index System (CODIS). The idea behind CODIS was to allow DNA information to be searched and traded on a national scale. This potentially would allow more unsolved crimes to obtain suspects, connect seemingly unrelated crimes, exonerate innocent suspects, and help convict the guilty. CODIS would have the potential to prevent crimes by catching repeat offenders earlier. In 1994 the DNA Identification Act (Adams, 2002) made a DNA database used strictly for law enforcement officially legal. Soon after, in 1998 the National DNA Index System (NDIS, the nation tier of

CODIS) was founded. The FBI finally had a full operational national DNA database. As of May 2002, CODIS included 153 laboratories representing 49 states, and assisted in 4,719 investigations. NDIS included 127 laboratories representing 41 states, and had over 900,000 convicted felon's DNA profiles (Adams, 2002).

CODIS is a hierarchical system. At the highest level is CODIS, which contains all the software used to maintain and run the DNA databases. CODIS also contains two separate indexes. Its forensic index contains DNA evidence from crime scenes, and the offender index has DNA profiles on convicted sex offenders (and other felonies) (US department of justice, 2000). CODIS is divided into three tiers: national, state, and regional. This allows DNA to be collected and catalogued under state and local laws. The national tier is called NDIS, and it allows every individual laboratory involved in the CODIS program to search through and exchange information with other cooperating laboratories. CODIS is further divided into state and local levels, where the state level is a state-wide collection of individual laboratories which make up the local level.

DNA samples are collected for the database in many different ways. Currently, all 50 states will take tissue (from a cheek swab) samples from convicted sex offenders to be added to the database. However, more and more states are beginning to take DNA samples from additional non-sex crimes. As of 2000, 6 states took DNA from all convicted felons, and one state took DNA from all arrested suspects (US Department of Justice, 2000). These DNA samples are sent to the CODIS laboratories, where they are analyzed and stored electronically in the CODIS database. Also DNA evidence found at unsolved crime scenes are sent to the laboratories for testing. Whenever new DNA is profiled and added to the system, it is checked against all other existing profiles. This is to link otherwise unconnected crimes. If a

DNA from one crime scene matches the DNA from another crime scene, investigators can combine information and come closer to a suspect. Two DNA profiles matching are called 'cold hits'.

Probabilities

DNA contains every piece of information that makes a person unique. However, it would take to many resources to profile every individual's entire genome for DNA testing. It is beyond the scope of forensics to even think about analyzing the entire genome of numerous forensic samples. Only recently has the entire human genome been sequenced. Because of this, forensic DNA is only tested on specific locations (or loci). However if only a portion of the genome is analyzed, the probability that two randomly chosen people have matching DNA increases. When only portions of the genome are analyzed, the probability of a positive match occurring on an unrelated sample depends on which loci are analyzed, how many are analyzed, and their individual frequencies in the population.

In the late 80's and early 90's when DNA evidence was first becoming commonplace, allele frequencies were not well characterized, so probabilities of a match were somewhat vague. Scientists would have to admit that they didn't know the exact probability of two random people's DNA matching (Rielly, 2001). Instead of knowing exact probabilities, scientists were only able to provide a range of probabilities depending on the loci tested. In early DNA court cases, the evidence was sometimes disallowed because the range of potential probabilities was too great to be of probative value. Scientists did not have enough samples in a randomly chosen sample database to accurately assign specific allele frequencies in the population, and thus match probabilities could also not be accurately assigned.

Although the CODIS database does not contain randomly chosen DNA samples from the human population, it does provide a larger numbers of samples for analysis than previously available. So DNA experts can now talk about the probabilities of a match with more confidence. It has recently been estimated that when 10 loci are tested, the chance of a random match is one in a billion (Williamson and Duncan, 2002). It is becoming standard for 13 loci to be tested. James Crow, a population geneticist, calculated that the probability of a complete match between profiles of two unrelated persons in a randomly mating population of Caucasian Americans is 1.74×10^{-15}, or 1 in 575 trillion when 13 loci are tested (Rielly, 2001). Today DNA evidence is almost universally accepted in courtrooms. These forensic loci were chosen because they vary greatly between individuals. They do not code for enzymes or serve other obvious functional purposes, otherwise their sequences would be highly conserved in human populations. Thus these forensic loci are often called 'junk DNA' because they appear to contain no specific genetic information.

Ceiling Principle

Because exact probabilities can not be determined, only ranges, some lawyers have argued against allowing DNA evidence in specific cases. If a DNA expert in court declares an exact probability, the opposing lawyer would be able to argue that it is in fact a range of probabilities thus discrediting the expert testimony. A strong defense against this argument is the "ceiling principle". The ceiling principle is based on being conservative with all probability estimates. For each locus tested, the weakest frequency within its range is used (i.e. if the frequency range of allele-X is 10^6 to 10^7, the 10^6 is used for forensic purposes, always favoring the possible chance of a random match). If 10 loci are analyzed, then their 10

lower-level frequencies are multiplied together to obtain the overall probability. Another way to state the evidence is to declare the entire range, not just a fixed number. Instead of saying that the probability is estimated to be 1 in 500 trillion, say that the probability is really a range between 1 and 500 billion and 1 in 500 trillion. Focus on the weaker estimate (which is still amazingly "unique") and claim that even if the probability was 1 in 500 billion, that it is beyond a reasonable doubt.

Benefits of a DNA Database

The FBI claims that the only way to rate the success of its CODIS program is to look at the crimes it has solved. In its twelve year history, CODIS has definitely seen its share of success stories, and has solved a large number of sensational crimes. A cold hit occurs when two apparently unrelated DNA samples in the database match. By 1999, CODIS had over 600 cold hits (US Department of Justice, 2000). By July 2000, Virginia alone had 183 cold hits when searching their database of over 120,000 individuals (Siegel 2000). In March 2000, New York found the state's first cold hit when a convicted offender profile matched crime scene evidence from a 21 year old murder (Block 2000). In 1995, an unidentified woman's body was found on an off-ramp along an interstate in Des Moines, Iowa. The FBI developed a DNA profile of the perpetrator, and in February 2000 they matched that profile to a Florida felon who was convicted of sexual assault (US Department of Justice, 2000). These cases not only give piece of mind to those affected by the crimes, but can also prevent future crimes. If a serial rapist commits two separate attacks, police would be able to connect these two crimes and prevent further attacks that could have happened.

The following sensational case further proves the benefits of the CODIS program.

> "A college professor was raped and murdered in Flint, Michigan in 1986. A search of the Michigan state fingerprint files was negative and no suspects were developed in the case. Five years later, a flight attendant was raped and murdered in a motel in Romulus, Michigan. Again, there were no suspects. In 2001, DNA from the 1986 offense was submitted to the Combined DNA Index System (CODIS) at the state level which matched it to the 1991 murder. The Flint Police Department's Cold Case Squad submitted latent fingerprints from the 1986 homicide to the FBI's Latent Fingerprint Unit. Three latent prints were searched using the FBI's Integrated Automated Fingerprint Identification System (IAFIS) and one of the latent prints was identified. Rather than immediately arrest the suspect, the police followed him and retrieved a napkin the suspect had used in a restaurant. DNA found on the napkin matched the DNA from both homicides and the suspect was arrested, charged with both murders and is awaiting trial." (Adams, 2002)

Solving unsolved murders and sex offenses is not the only use for such a database. In 1999, Spain founded a national database, called the Phoenix Programme whose sole purpose is to solve missing persons cases. This program has two databases. There is one database for DNA samples given voluntarily from a missing person's maternal relative, and one database for profiles from unknown human remains.

There are many benefits for a database of publicly donated DNA. One benefit is a database for medical research such as finding links between genes and many human conditions. Another benefit would be to better calculate specific allele frequencies for forensic purposes. Currently, all frequencies are based on the felon population. If that population is biased towards a specific population (i.e. contains a higher percentage of an ethnic group than the general population) then the resulting frequencies would be biased as well. If there was a publicly donated database, allele frequencies would be more accurately known. There is a need for this kind of public database. This is a need that has gone largely unfulfilled.

Cons – Backlog and Statute of Limitations

When CODIS was first founded, the only DNA samples that were being taken were from convicted sex offenders. Soon state databases grew past the speed at which samples could be analyzed and processed. As more states accumulate DNA samples from more crimes, crime labs get more and more samples that need to be added into the database. Current laboratories do not have the capacity to meet the demands of the state.

For top priority samples, results can be received within 24 to 48 hours. That includes database searching, DNA identification, and results sent to the investigator (Siegel, 2000). This would be for a top priority case. For normal cases, it could take months, or longer.

In late 1999, it was estimated that the sample backlog consisted of over 500,000 samples from felons (Rielly, 2001). The backlog problem can be best seen in the large amount of rape kits (DNA evidence gathered at the scene of a sexual assault) "gathering dust in storage" (Adams, 2002). It is estimated that there are over 180,000 rape kits waiting to be processed (Block, 2000).

The biggest problem with the sample backlog is the statute of limitations laws. All non-murder crimes have a certain period of time before the felon can no longer be convicted of a crime. The crime is based on the idea, that over time evidence and clues become damaged, and that over time is would be easier for an innocent man to be convicted of a crime he did not convict. But when those laws were passed, there was no way for anyone to predict evidence such as DNA, which remains useful for incredible periods of time after they are left at the crime scene. Because of the backlog, the statute of limitations is running out on cases while the DNA evidence goes unanalyzed. New York has rape kits over 10 years old waiting to be analyzed. Most of the samples are past the statute of limitations, and 'time is running out

for the rest' (Block, 2000). However, if a convict is eventually caught of a crime still within the statute of limitations, the courts might be able to tack on his previous crimes in addition to his current one, which might result in a harsher punishment (Rielly, 2001).

The government is doing their best to relieve this backlog problem. In 1999 the US congress provided the states $15 million in order to assist with reducing their backlog providing that 1% of the funds be used to solve current unsolved cases (Rielly, 2001). This and other efforts to eliminate backlog helps, but as long as the current trend of states expanding their database laws holds, backlog will still exist. When New York law changed to include sampling from a larger amount of crimes, the amount of samples increased tenfold including retroactive samples. "In the month of December, under the new law, for example, we received as many samples in that month as we received under the old laws in the previous year" (Block, 2000).

Database Ethics Introduction

The collection of DNA information and adding it to a national database raises some deep ethical questions. Since DNA stores such an incredible amount of information about an individual it could easily be misused. Scientists can currently see a predisposition to literally hundreds of diseases from looking at a DNA sample, and it is predicted that in the future you could be able to tell many behavioral traits from aggression to anti-social behavior. It is easily conceivable that the leap could be made from only doing DNA analysis on convicted felons, to doing DNA sampling from every newborn child, in order to screen them for possible genetic diseases and preconditions. It is also easily conceivable that your DNA information could easily get in the hands of people that could discriminate against you based

on your DNA. Insurance companies wouldn't sell a policy to someone who has a higher risk of heart disease. Companies might not hire someone who has a high risk of becoming dependant on alcohol and drugs.

When dealing with the ethical issues of DNA databases we must consider whose DNA should be included in it. Forensic DNA databases only contain 13 analyzed loci. Usually, only their lengths are known. These loci contain no medically valuable or exploitable information to the best of our knowledge, but there are still many public fears that must be addressed. We must consider if such a database violates basic rights. Also, a lot of the fear behind the future of DNA information lies behind misinformation and propaganda. The difference between fact and fiction must be addressed as well.

Database Ethics – 4th Amendment Rights

The 4th Amendment protects a citizen's rights against illegal search and seizure. In order for police to gather evidence by searching, they must first get a warrant and have probable cause. This maintains the United State's tradition of innocence until proven guilty. It has been argued in courts that taking DNA samples from convicted felons violates the 4th Amendment. These cases have mostly been defeated in courts. It has been maintained that these laws do not violate the 4th Amendment because once a felon is convicted they lose certain rights along with a compromised right to privacy. Also courts have held that such a warrant is not required because the statute applies uniformly to all specified offenders. DNA samples are treated like fingerprints in that they are used solely for prosecution and the solving of future crimes. These factors outweigh the felon's right of privacy. A Massachusetts court ruled that "A bodily intrusion with or without the use of force, can only

be considered reasonable if probable cause exists to believe the person in question participated in the criminal act for which a. . .sample is relevant evidence" (Hoyle 1998).

Great Britain currently has a DNA database that is much farther ahead than the United State's but it is done much differently. Great Britain isn't held under 4th Amendment laws, and can therefore perform DNA searches that would be otherwise illegal in the US. Britain will conduct DNA 'sweeps' where the police will go door to door and collect DNA from every male in the area of a sexual assault. These samplings are all voluntary but it isn't without social pressure. "If samples are to be taken from the convicted, from suspects, and from anyone who volunteers to have a sample taken, the rules of consent become clouded" (Williamson and Duncan, 2002). When everyone on your block is being tested, it seems as if you have something to hide if you choose not to consent to a DNA test. Therefore, these DNA sweeps cannot be considered fully voluntary. Surprisingly, recent trends have shown that actions like these are starting to be seen in the US. Very recently, Louisiana has conducted a search for a serial killer by collecting DNA samples from over 1,000 men who match descriptions of the killer based on phone tips (Noel, 2003).

Ethics – Whose DNA Belongs in a Database?

Current beliefs hold that convicted sexual offender's DNA should be in a database. The benefits of such a system are clear, and currently all 50 states collect DNA from individuals convicted of sex crimes. Recent trends show that more criminal's DNA are being added to databases. By 2000, six states collected DNA from individuals convicted of any felony. 23 states collected DNA from convictions of certain misdemeanors, and 26 states will

collect DNA from categories of juvenile offenders (Kimmelman, 2000). The success of widening the databases is obvious. Susan Gaertner, one of Minnesota's leading advocates of DNA technology, "obviously, when you quadruple the database of DNA samples, you are going to exponentially increase the likelihood you will be able to solve these crimes" (Pattison, 2000). A large proportion of Virginia's cold hits in sex offense cases are the results of DNA gathered from nonviolent crimes such as larceny and drug offenses (Adams, 2002).

Today the numbers are much greater all across the board. Britain is much further along on this trend than the US. Currently Britain will collect samples "from anyone who is suspected of, charged with, reported for or convicted of a recordable offence. The United Kingdom is aiming to hold the DNA profile of nearly 1 in every 15 people in Britain" (Williamson and Duncan 2002). Because the size of the country is so small, Britain doesn't have the same backlog problem that the US has. Even though the British police are required to destroy evidence after the exoneration of a suspect (Rielly, 2001) civil rights activists argue that DNA sampling at arrest violates the rights of the innocent. This trend has been moving over to US soil as well. Currently Louisiana has a law that allows DNA sampling at arrest as Britain already has but only for individuals suspected of violent sexual felonies (Rielly, 2001). Both the mayor of New York, Rudolph Guiliani and the former New York police chief Howard Safir have been vocal for New York to have DNA sampling at arrest. North Carolina has even gone to the lengths of proposing legislation to the same effect (Kimmelman, 2000).

Databases are moving quickly away from just criminal DNA though. In 1999 the genome for all of Iceland was sold for $200 million dollars to a company named Decode (Kahn 1999). This raises many ethical issues. How does a government have the right to sell the genetic information of the entire country? Does it have the right to sell it to a corporation?

A corporation would have plenty of opportunities to exploit the information it received. It would be easy for the company to reach many conclusions about Icelanders in general that could lead to discrimination. In the 70's African Americans were discriminated against by insurance companies because they had a higher chance of carrying sickle cell syndrome. If a high percentage of Icelanders had a genetic predisposition to a genetic disease or condition, then the entire country could easily be discriminated against because of it. This kind of database is likely to actually contain medical information in it, unlike a forensic database which contains mostly 'junk' DNA.

Databases with different functions other than forensics are appearing. These databases serve a more scientific purpose. These are databases where the samples are from voluntary subjects. The Iceland database is an example of such a database. The function of these database ranges from medical research to defining more accurate allele frequencies. Contributors to these databases would have to be anonymous because the information given is of a more personal nature than in forensic databases.

In March of 2002, the US government took DNA samples from wartime detainees and added them to the national database as a separate index. "John Ashcroft told reporters that putting the DNA samples into the database 'would assist law enforcement officials in the identification of those who might seek to harm the United States and the U.S. interests through terrorism either now or in the future" (Bohn 2002). The Terrorist Identification Database Act of 2003 is part of the Patriot Act II. The purpose of the act is for "detecting, investigating, prosecuting, preventing or responding to terrorist activities" (Scheeres 2003). In essence it gives the government the power to collect the DNA of people even suspected of terrorism. As with the rest of the patriot act, people are protesting claiming that this will give

the government too much power. With penalties of up a year in jail and a $200,000 fine, these perhaps completely innocent Americans will be forced to give up their DNA information. Under this act, samples could be kept indefinitely. This means that in the future the DNA could serve any number of uses other than just identification.

Ethics – Genetic Discrimination: Insurance

Insurance is an integral part of our culture. Health insurance allows expensive hospital visits to become affordable, while life insurance allows family members to pay for costly funeral services. It is a common fear that a healthy individual might lose his or her health insurance if the insurance company discovers a potential condition or disease. Losing insurance could make someone's life a struggle financially. Since DNA contains information that could cause insurance companies to deny coverage, people worry that insurance companies will discriminate based on their DNA. Databases do not contain the entire genome, only specific loci. Though information contained in a forensics database has no medical use, there is still public fear of such a database being created. "A recent study shows that 1/3 of people expressed concern that DNA testing could cause them to lose their health insurance. Another study showed that fear of health insurance discrimination was the most frequent reason for declining genetic counseling services" (Rothenberg and Terry, 2002).

Currently there are many diseases and preconditions that can be found through DNA analysis. Huntington's disease is an untreatable genetic disorder that will affect every person carrying the gene. The BRCA1 and BRCA2 genes when mutated can indicate a higher risk of breast cancer. Also, pharmacogentic testing can reveal how some people with certain

genotypes will react to certain medications (Sasjack 2002). These are all conditions that insurance companies might discriminate against.

There are also many multifactor preconditions found in the DNA, which through lifestyle changes could be avoided. For example a person with a high risk of heart disease can easily be combated through careful diet and exercise. The fear that one could lose health insurance based on an avoidable condition is common.

Most fears of losing insurance are based on the insurance company's actions in the 1970s. In the 1970s, African Americans were being denied insurance coverage for being carriers of a mutation that caused sickle cell anemia. They were discriminated for carrying just the sickle cell trait, and not the actual condition (Sasjack 2002). So far, 45 different states have passed various laws preventing genetic discrimination from insurance companies. Most of these laws forbid insurance companies from getting people's DNA tested, or to use DNA evidence as a reason to deny insurance coverage (Rothenberg and Terry 2002).

Representatives for the large insurance companies have spoken out against the public fear against genetic discrimination. There have been little to no proven cases of genetic discrimination by insurance companies. Most fears are based on future predictions and worst-case scenarios. The facts are that coverage is given to 95% of all Americans who apply, and 90% of these policies are at a standard rate (Nowlan 2002). Insurance companies claim that they give the existence of the BRCA1 and BRCA2 genes the same risk factor as smoking cigarettes. Insurance companies have also said that predisposition for future conditions does not rule people out for insurance. "Other than Huntington's disease, genetic risk in a healthy adult does not preclude affordable insurance. Predispositions to common, multifactorial

diseases would be much less" (Nowlan 2002). Also, currently there are no national databases that contain medical information that the insurance companies would find of interest.

Ethics – Genetic Discrimination: Employment

On the other side of the discrimination coin, is how employers will react when tempted with DNA information. Business is business, and employers will always look out for what is best for the company. If there was any way for employers to use genetic information in favor of the company, they would probably take it. Employers could easily use genetic testing to find if a potential employee might have a condition that would limit his or her job performance. The employer has the right to fire or not hire based on an impairment that is job related (Sasjack, 2002).

For example, if a specific job involves a lot of strenuous exercise, then the employer wouldn't want to hire someone with a potential heart condition. If a job requires working closely with a certain chemical, the employer wouldn't hire someone who had a high risk to be negatively affected by that chemical. These are all hypothetical scenarios, but in 2002 the first case of genetic discrimination in the work place was settled in court. 36 workers at Burlington Northern in Santa Fe, New Mexico complained of job-related carpal tunnel syndrome and were brought in for extensive medical tests. During these medical tests the company took blood samples for the purpose of DNA testing. If the company found that the workers were predisposed to carpal tunnel syndrome, then they would fire the employees. The courts awarded the 36 workers $2.2 million to be split among them (Szekely, 2002).

Ethics – Public Fears and Knowledge

Most of what is slowing the advance of DNA databases is public fear and the spread of misinformation. People are afraid that their DNA will be available to all for the right price. This DNA could then be used for any number of ways against them. If, because of a database, insurance companies and employers could get your DNA they could use that information to deny insurance coverage and to fire you. Fears range from the conceivable, to paranoid fantasies. One convict, whose DNA was recently taken for the national database, was worried about the DNA being used for cloning experiments (Block, 2000).

Other fears though are based on current trends and worst-case scenarios. It is a fact that as costs for DNA analysis decreases, pressure will increase to add more and more DNA into the database (Westervelt 1998). As the DNA samples increase, the question is what information will be present in the database, and what will be done to the DNA? Charles Samuelson, executive director of the Minnesota Civil Liberties Union said, "What we're afraid of is that a couple of bad court decisions, and a couple of pieces of bad legislation, and this DNA stuff could get out of hand. Basically we're afraid of '1984'" (Pattison 2000). A general fear is that the government will go back and use the collected DNA that hasn't been destroyed for uses other than forensics. For example, the politicians might want to look at all that DNA to find the 'aggression' gene. Something like that could label people from an early age as being a felon because they hold this gene. It could become a self-fulfilling prophecy for these people. People are also terrified that because of an error in the laboratory, or a contamination at the crime scene, this could lead to being wrongly accused. With a piece of evidence as strong as DNA, it would be next to impossible to plead your innocence.

In order to avoid most of these issues, safeguards must be in place to guarantee that there is no misuse. There must be protection from the crime scene to the laboratory to make

sure that there is no contamination. The laboratory must have safeguards to ensure that all DNA is analyzed correctly, and that no mistakes are made. There must also be safeguards against tampering with DNA evidence. Finally DNA databases with criminal DNA must be kept separated from other (research) databases.

The government has foreseen these ethical issues and has made efforts to put in place effective safeguards. "The DNA Advisory Board, recommended two sets of quality assurance standards to the FBI Director, Quality Assurance Standards for Forensic DNA Testing Laboratories, and Quality Assurance Standards for Convicted Offender DNA Databasing Laboratories. Both standards were approved by the FBI Director and were effective October 1, 1998 and April 1, 1999, respectively" (Adams, 2002). These assurance standards are in place in order to effectively make sure that every piece of DNA in the databases was analyzed in a sterilized laboratory, and quality control procedures were made so that there were no mistakes. It also protects against tampering with any DNA evidence. In addition to these standards, the only information that is entered in the database surrounds these specific 13 loci. These loci contain no specific information and are considered 'junk DNA'. Furthermore most States will dispose of DNA evidence after it has been analyzed and entered in the database. This ensures that the original DNA sample will not be used to obtain additional information besides that on forensic loci. Other databases that do contain possibly medically useful information should be kept completely anonymous. This is to ensure that no information is misused.

Chapter-6: Conclusions

Chapter 1

DNA technology is one of the most exciting fields in biology. Within the understanding of DNA comes a deeper understanding of human beings. The first research into DNA genes was done by Gregor Mendel in 1865 who realized that the traits of parents were passed to their offspring. He tested this with pea plants. He called the factor for traits being passed *genes*. The idea of passable traits was the beginning of discovering the chemical substance that contains genes, DNA. Though Mendel never discovered that DNA was the cause of traits being passed, he made a very important first step.

Later, when physical DNA was discovered, Mendel's genes were re-defined as discrete portions of the DNA molecule that contain the directions for making a individual proteins that influence a metabolic trait. These proteins are made by arranging strings of amino acid in a specific order. DNA was found to be the instructions for building these proteins. DNA or Deoxyribonucleic acid is a polymeric molecule that is composed of four different building blocks. These four different building blocks are adenine, cytosine, guanine, and thymine, which are also known as A, C, G, and T.

DNA fingerprinting is the method of analyzing specific regions of the DNA that have been shown to be unique between individuals. Most of our DNA is the same for all humans, however portions vary considerably from individual to individual, and these regions or loci are analyzed forensically. There are three standard ways to perform DNA fingerprinting. The oldest method is restriction fragment length polymorphism, or RFLP. This method used restriction enzymes to cut up purified DNA into segments that correspond to different loci of

various lengths that when put onto an agarose solution and put into an electric field would sort them out by length. This is a very exact method but is long and tedious, and requires a relatively large amount of starting material. The RFLP method has over 200 steps to perform.

The second method is the Polymerase Chain Reaction or PCR. The PCR method is based on amplifying DNA from a source. This DNA is then examined by slicing it up into segments using restriction enzymes and then gel electrophoresis to produce a visible picture with the help of some fluorescent staining. This method is useful because it can be performed with very little original DNA, is quicker than other methods, and does not have any radioactive waste.

The third and most frequently used method in forensics is the STR method, or Short tandem repeats. This method is similar to RFLP but instead uses PCR to amplify specific STR loci whose lengths vary from individual to individual. A simple gel is then run to determine the size of the amplified bands. This technique is highly accurate, involves no restriction enzymes or radioactivity, and cuts the number of steps from 200 to 50.

Chapter 2

DNA is a very important forensics tool. It is much more accurate than fingerprinting and can be obtained from a variety of sources at a crime scene. Though a person can change many physical aspects of himself, he will never be able to change his DNA. DNA evidence has been appearing in courtrooms for the past 15 years.

DNA evidence is much more accurate than other forms of court room evidence. Eyewitness accounts are only 50% accurate. However, DNA evidence can not be considered 100% accurate though. In Las Vegas, due to human error, Lazaro Sotolusson's name was

accidentally placed on the wrong DNA profile, and he was falsely arrested under two rape charges. Human errors like this are considered to be the weakest-link of DNA evidence.

Many things at a crime scene will leave DNA evidence. Mucus, blood, sweat, semen, skin, tissue, hair, dandruff, saliva, bone, and teeth are all useful samples to be collected from a crime scene. Less useful samples would be feces or urine, biological samples that were contaminated with soil and samples from certain substrates like jeans or denim, which have been known to mess up DNA analysis. Very little sample is needed from DNA rich samples such as blood, semen, and tissue. DNA evidence is literally everywhere at a crime scene.

Precautions must be taken when collecting DNA evidence. Police must make sure that evidence is not contaminated before it is examined. It is important that while collecting, gloves are worn at all times and changed regularly. Touching the face must be avoided before touching samples. Also people must avoid spitting, coughing, and sneezing. Samples must be air-dried, kept in a paper bag, and kept dry and cool to avoid DNA degradation.

Chapter 3

The introduction of any new technology in the courtroom is not a straightforward process. A series of landmark court cases over the past 80 years or so has defined the conditions under which a U.S. judge can accept a new technique as evidence. As the cases summarized in our chapter-3 show, great care must be given to any new technology. If evidence is introduced that is based on a scientific theory that is later proven to be false, there could be false convictions.

The case of Frye vs. US (1923) set the first legal precedent for using scientific evidence. James Alfonso Frye was placed under a systolic blood pressure deception test,

otherwise known as a lie detector test, and passed it. The prosecution objected on the grounds that the scientific test was not generally recognized in the scientific community. The court agreed in a decision that later became known as the *Frye Standard*, that before any scientific evidence could be introduced in a court of law, it must first have *general acceptance* in the scientific community. An expert witness who has studied a scientific method for years would often be called in court to explain that method.

The Frye method of accepting scientific evidence was expanded upon in 1975 with the Federal Rules of Evidence (rule 702). This rule also allowed for an expert witness to testify on specified knowledge, but stated that instead of being generally accepted in the scientific community, a method must be proven *reliable*, and the methods must be *applied correctly*. The decision on the reliability of a scientific method would be made by the presiding judge.

DNA evidence was first passed uncontested in a U.S. court in the 1988 case Andrews vs. Florida. In 1988 a Florida man by the name of Tommy Lee Andrews was convicted of rape. DNA evidence found at the scene of the crime (in the form of DNA) was tested against Andrews DNA. A positive match was found, and an expert witness testified that only 1 in 10 billion individuals could have that same pattern. The jury returned a verdict of guilty, and Andrews was sentenced to 22 years imprisonment by the Circuit Court in Orange County, Florida.

The 1989 case of People vs. Castro, developed further the laws concerning the acceptance of DNA evidence. In this murder case, a match was found between blood found on a suspect's watch and a victim's DNA. However, the court concluded that the DNA analyzed was not reliable because of a laboratory error. As a consequence of these errors, the court recommended that a new standard procedure be identified and adopted for DNA testing.

The FBI responded by establishing a technical working group on DNA methodology (TIWGDAM) who devised the standard procedures in use today.

Chapter 4

Although the above mentioned landmark cases established legal precedent in the US for accepting DNA evidence in courts, most of the public has not heard of those cases. Instead, the public usually learns of DNA fingerprinting technology evidence in various sensational cases, which may or may not have taught us anything new about DNA evidence. For example, while Thomas Jefferson was still President of the United States, allegations were made that he had fathered children with his slave Sally Hemings. Such a relationship would be considered unacceptable back in 1802, and would be outrageous for the President to have an interracial affair. Though nothing could be proven in the 1800's, recent DNA technology shed some light on this mystery. Recently, scientists gathered DNA from the descendants of the Hemings and Jefferson lineages for DNA analysis and comparison. A study reported that there was a match in the Y-chromosome between the Hemings and Jefferson descendants. The Y chromosome DNA is passed from father to son and rarely changes or mutates over the course of several generations. This concludes that a Jefferson fathered the children of Sally Hemings, but it does not prove which male Jefferson. Any other member male member of the Jefferson family has an equal chance of been the father of Sally Heming's children.

The Russian legend of Anastasia is about the daughter of the Romanov royal family that was all murdered during the Bolshevik revolution. The legend is that Anastasia was the

only person to live the execution of the royal family. In 1920, and unidentified woman was found in an asylum who had an uncanny resemblance to Anastasia. She also knew very intimate details or royal life that only Anastasia would know. When the woman claiming to be Anastasia died in 1984, they tested the DNA left on a drop of blood, a strand of hair, and a tissue sample, and compared it to known Romanov relatives and blood taken from a Polish factory worker that some claim she was. The DNA samples matched the DNA of Anna Anderson, a missing Polish factory worker, and did not match any tested Romanov relative. It has been concluded that the unidentified woman was really Anna Anderson, though many still believe she was Anastasia.

The media circus known as the O.J. Simpson trial will be known as the trial of the 20th century. O.J. Simpson was charged with double murder charges for the death of both his wife Nicole Brown Simpson and Ronald Goldman. Blood found at the scene of the crime matched O.J. Simpson's. The victim's blood was also found in O.J.'s car and home. There seemed no doubt that the DNA evidence was conclusive. There was a 1 in 170 million chance that the DNA belonged to someone other than O.J. Simpson. With all this very incriminating evidence, the defense began to argue that there was tampering of DNA evidence, faulty lab results, and conspiracy theories of placed evidence and racist cops. Eventually the jury sided with the defense, and found O.J. Simpson innocent despite the damning DNA evidence and the defense's convoluted theories.

Chapter 5

DNA databases serve two major purposes. The first is to serve as a testing repository for a large number of randomly chosen samples to allow a more precise determination of

allele frequencies for specifically chosen forensic loci. The larger the number of samples in the database, the more accurate is the determination of probability of a match. The second reason for having a database is to collect DNA samples from known offenders, so their samples can be compared against future crime scene samples.

In order to better solve crimes, the government needed a nationwide, searchable, DNA database. The FBI founded the Combined DNA Index System (CODIS) in 1990. CODIS was a searchable DNA database that was run at local and state levels, with a national tier called NDIS. This database is currently used to compare crime scene samples for what is termed "cold hits", a match to a previous offender. CODIS allows more unsolved crimes to be solved by obtaining more suspects, connecting seemingly unrelated crimes, and exonerating innocent suspects. As of May 2002, CODIS included 153 laboratories representing 49 states, and it assisted in 4,719 investigations. NDIS included 127 laboratories representing 41 states, and had over 900,000 convicted felon's DNA profiles.

Another use of the DNA databases is to better understand the probability of a match between two random people's DNA. Although no two individuals have the exact same DNA sequence, forensics does not have the time or money to completely sequence crime scene DNA. Instead, DNA testing tests certain locations or loci. These loci have different frequencies within certain populations. The probability of a match between two randomly chosen people is based the number of loci tested, and the allele frequency (alternate forms of a gene) within the population. Using DNA databases, a more specific probability of a random match can be found. This is because with a higher population of DNA analyzed, the more we know about each specific allele frequency.

The CODIS program has been very successful. A cold hit occurs when two apparently unrelated DNA samples in the database match. By 1999, CODIS had over 600 cold hits (US Department of Justice, 2000). By July 2000, Virginia alone had 183 cold hits when searching their database of over 120,000 individuals.

Other benefits of DNA databases come from publicly donated DNA databases that exist for medical reasons and help find links between certain human genes and various medical conditions.

Many cons of these databases exist. For example, there is a tremendous backlog problem for the CODIS databases. It takes time and money to analyze a crime scene sample, and scan it against CODIS, and a large number of samples await analysis. This backlog is costing millions of dollars, and in the meantime, many criminals are still roaming free waiting for the statute of limitations on their crimes to run out. There is also a controversy over the ethical issues of collecting DNA information from people. Many people claim that gathering such information is a violation of their rights. They also claim that such information could be used to discriminate against them for medical or life insurance purposes, or by prospective employers. Although it is true that blood samples donated by an individual could be used for such purposes, and great care should be used to destroy the original samples donated to any database, most experts claim that DNA information present in a criminal database only contains information on 13 loci, and these loci contain no medical or otherwise useful information. Publicly donated databases are kept anonymous and couldn't be used for discrimination purposes. Because of public fears these issues will probably not be resolved anytime soon.

Bibliography

Adams, Dwight E (2002) Congressional Statement: "The FBI's CODIS Program". Federal Bureau of Investigation, U.S. Department of Justice. http://www.fbi.gov/congress/congress02/adams051402.htm

"An Interview with DNA Forensics Authority Dr. Bruce Weir" (2000) http://www.piopio.school.nz/weirfing.htm

"Atlanta Salmon Federation Research". http://www.asf.ca/Research/resrch03.htm

Bardsley M, and Bell RS (2002) The Boston Strangler. http://www.crimelibrary.com/serial_killers/notorious/boston/index_1.html?sect=1

"Basic Genetics and the Australian Shepard". (2001) http://www.asca.org/Education/Advanced/fingerprint.htm

Block, Melissa (2000) "DNA Evidence) (Audio) All Things Considered, National Public Radio, May 25. http://discover.npr.org/features/feature.jhtml?wfId=1074645

Bohn, Kevin (2002) Justice wants detainees' DNA put in FBI database Washington, DC. http://www.cnn.com/2002/LAW/03/05/justice.detainees.dna/index.html

Bruzel, Alan "DNA Fingerprinting" (1998) http://dwb.unl.edu/Teacher/NSF/C08/C08Links/chemistry.about.com/science/chemistry/library/weekly/aa070698a.htm

"Can DNA Demand A Verdict" (2003) http://gslc.genetics.utah.edu/features/forensics/

Chebium, Raju (2000) Virgina pioneers development of DNA database to solve crimes. http://www.cnn.com/2000/LAW/10/24/states.dna.virginia.cr/index.html

CLS, Commission on Life Sciences (1992) DNA Technology in Forensic Science. Washington, DC: The National Academies Press, 1992. Pg. 135-151. http://books.nap.edu/books/0309045878/html/135.html#pagetop

Coleman, H and Swenson E (1994). DNA in the Court Room: A Trial Watcher's Guide. Seattle, Washington: GeneLex Press, 1994. http://www.genelex.com/paternitytesting/paternitybook1.html

Court of Appeals for the District of Columbia, (1923) 54 App. D.C., at 47, 293 F., at 1014, Frye v. US

Daley, John D. and Thomas F. Allen, Jr. (1999) "Judicial Gatekeeping in Massachusetts". Harvard Law School, 1999.

http://cyber.law.harvard.edu/daubert/ma.htm

"DNA Evidence, when properly collected and analyzed, should not be called into Question"(1996) http://www4.nas.edu/news.nsf/isbn/0309053951?OpenDocument

"DNA Fingerprinting 3: Southern Blot Analysis." (2001) http://www.edvotek.com/pdfs/311.pdf

"DNA Fingerprinting by PCR Amplification of HLA Genes" http://www.aic.gov.au/publications/proceedings/02/easteal.pdf

"DNA Fingerprinting using VNTR". (1999) http://www.people.virginia.edu/~rjh9u/vntr1.html

"DNA Forensics" (2002) http://www.ornl.gov/hgmis/elsi/forensics.html

"DNA Forensics Problem Set 1" (1996) http://www.biology.arizona.edu/human_bio/problem_sets/DNA_forensics_1/01t.html

"DNA Forensics Problem Set 2" (1997) http://www.biology.arizona.edu/human_bio/problem_sets/DNA_forensics_2/06t.html

"DNA From the Beginning". (2002) http://www.dnaftb.org/dnaftb/

"DNA Testing: An Introduction For Non Scientists An Illustrated Explanation" (1998) http://www.scientific.org/tutorials/articles/riley/riley.html

DSMZ: "DNA Fingerprinting" http://www.dsmz.de/mutz/mutzdnaf.htm

Editorial (1996) Romanovs Find Closure in DNA. *Nature Genetics* 12 (4) 339. http://www.nature.com/ng/wilma/v12n4.867853248.html

Federal DNA Database Law Violates Fourth Amendment (2002) November 13. *Criminal Law Reporter,* Volume 72, Number 7. http://litigationcenter.bna.com/pic2/lit.nsf/id/BNAP-5FVMKA?OpenDocument

"Fingered by DNA". (2001) http://whyfiles.org/126dna_forensic/3.html

"Forensic Science Timeline" http://www.forensicdna.com/Timeline020702.pdf

"Forensic Science and Genetic Variation" (2002) http://www.genaissance.com/dnasciences/basicsArticle/basicsArticle_Forensics.asp

Gene Almanac. "DNA Fingerprinting". http://www.dnalc.org/resources/aboutdnafingerprinting.html

Green, E., Murry, P., and Nesson, C. – Downing (2003)
United States v. Downing, 753 F.2d 1224 (1985)
http://www.law.harvard.edu/publications/evidenceiii/cases/us_v_downing.htm

Green, E., Murry, P., and Nesson, C. – Frye (2003)
Frye v. US, 293 F. 1013 (D.C. Cir. 1923)
http://www.law.harvard.edu/publications/evidenceiii/cases/frye.htm

Green, E., Murry, P., and Nesson, C.– Rule 702 (2003)
Rule 702, Testimony by Experts
http://www.law.harvard.edu/publications/evidenceiii/rules/702.htm

Green, E., Murry, P., and Nesson, C. – us-v-do2 (2003)
United States v. Downing, 609 F. Supp. 784 (E.D. Pa. 1985)
http://www.law.harvard.edu/publications/evidenceiii/cases/us-v-do2.htm

"Handbook of Forensic Services" (1999) Federal Bureau of Investigation, U.S.Department of Justice.
http://www.fbi.gov/hq/lab/handbook/examsdna.htm

Harris, Tom (1998) "How Luminol Works". HowStuffWorks, Inc.
http://www.howstuffworks.com/luminol.htm

"How DNA Technology Is Reshaping Judicial Process Outcome" (2001)
http://www.whitehead.mit.edu/cee/pdfs/Issuebrief502.pdf

Hoyle, Russ (1998) The FBI's National DNA Database. *Nature* **16**(11): 987.

InfoPlease: "Applications" (2000) http://www.infoplease.com/ce6/sci/A0857788.html

Infoplease "DNA Fingerprinting: Applications." (2000)
http://www.infoplease.com/ce6/sci/A0857788.html

InfoPlease "Methods" (2000) http://www.infoplease.com/ce6/sci/A0857787.html

Ishipress-Drfoster (1998) Historian Renews Criticism of DNA in Jefferson-Hemings, January 6, 1999. http://www.ishipress.com/drfoster.htm

Johnson B (2000) Massachusetts Interprets Daubert v. Merrell Dow Pharmaceuticals, Inc. in Comm. v. Lanigan (1994) and In re Case of Canavan (1999).
http://www.falseallegations.com/daubert.htm

Kahn, Jeffrey P. (1999) "Attention Shoppers: Special Today – Iceland's DNA". Center for Bioethics, University of Minnesota.
http://www.cnn.com/HEALTH/bioethics/9902/iceland.dna/template.html

Kimmelman, Jonathan (2000) The promise and perils of criminal DNA databanking. *Nature* **18**(7): 695 – 696.

Kramer, Robert E. (2002) "DNA Evidence Collection Principles". Iowa Division, International
Association for Identification. http://www.geocities.com/cfpdlab/DNA.htm

Lavoie, Denise (2001) DNA evidence stirs doubt in Boston Strangler case.
http://www.latimes.com/news/nationworld/wire/sns-bostonstrangler.story

Linder, Doug (2000) The Trial of Orenthal James Simpson.
http://www.law.umkc.edu/faculty/projects/ftrials/Simpson/Simpsonaccount.htm

"MedicineNet.com" (2003) http://www.medterms.com/script/main/art.asp?articlekey=4807

Noel, Josh (2003) Disappointment goes with job of hunting killer. May 1.
http://2theadvocate.com/ns-search/stories/050103/new_hunt001.shtml?NS-search-set=/3ef26/aaaa08377f2669e&NS-doc-offset=0&

Nowlan, William (2002) A Rational View of Insurance and Genetic Discrimination.
Science **297**: 195-196.

O'Connell, Ann Meeker. "How DNA Evidence Works"
http://science.howstuffworks.com/dna-evidence.htm

Olivier, Nick (2001). THE ROLE OF DNA IN THE INVESTIGATION OF CRIME: A CASE STUDY OF SOUTH AFRICA INVESTIGATORS. Technikon, SA: Police Practice Programme Group, 2001.
http://www.crimeinstitute.ac.za/2ndconf/papers/olivier_dna.pdf

Pattison, Kermit (2000) "Minnesota to widen collection of DNA" St. Paul, Minnesota.
http://www.cnn.com/2000/LOCAL/westcentral/06/27/pio.dna.database/index.html

"Problems with DNA Fingerprinting"
http://www.biology.washington.edu/fingerprint/problems.html

Puit, Glenn. "Changes proposed in DNA handling" (2002)
http://www.reviewjournal.com/lvrj_home/2002/May-15-Wed-2002/news/18751101.html

Ramsland, Katherine (2003) The DNA Revolution.
http://www.crimelibrary.com/forensics/dna/

Reporter - State of Ohio, (1992)
Reporter's Office of the Supreme Court of Ohio, 1992.
http://www.sconet.state.oh.us/Rod/Documents/0/1992/1992-Ohio-53.doc

Rielly, Phil (2001) Legal and Public Policy Issues in DNA Forensics. *Nature Review: Genetics* **2**: 313 – 317.

Rodin, Norah (2002) Forensic Science Timeline. http://www.forensicdna.com/Timeline020702.pdf

Rothenberg, Karen, and Sharon Terry (2002) Before It's Too Late: Addressing Fear of Genetic Information. *Science* **297**: 196-197.

Sasjack, Scott (2002) Genetic Discrimination and Rhode Island Policy. http://www.healthri.org/genetics/genetic_discrim_rep.pdf

Scheeres, Julia (2003) Fears About DNA Testing Proposal, March 31. http://www.wired.com/news/print/0,1294,58270,00.html

Seigal, Robert (2000) "DNA Gathering (Audio) All Things Considered, National Public Radio, July 27. http://discover.npr.org/features/feature.jhtml?wfId=1080047

Smith, D, and Wade N (1998) DNA Tests Offer Evidence That Jefferson Fathered a Child With His Slave. http://www.ishipress.com/dna-jeff.htm

Szekely, Peter (2002) Railroad to Pay $2.2 Million in DNA Test Case Illegally Testing Workers for Genetic Defects, May 8, Reuters. http://www.mindfully.org/GE/GE4/Railroad-Workers-Genetic-Defects8may02.htm

"Techniques of DNA testing". (1996) http://arbl.cvmbs.colostate.edu/hbooks/genetics/medgen/dnatesting/dnatest_tech.html#eg3

"The FBI's combined DNA Index System Program" (2000) Federal Bureau of Investigation, U.S. Department of Justice. http://www.fbi.gov/hq/lab/codis/brochure.pdf

Tsarskoe (1999) Her Imperial Highness Grand Duchess Anastasia Historical Society. http://www.concentric.net/~Tsarskoe/

TWGDAM (2003) TWGDAM Guidelines for a Quality Assurance Program for DNA Analysis C*rime Laboratory Digest* (1991) 18:44-75. http://www.cstl.nist.gov/div831/strbase/twgdam1.htm

U.S. Department of Justice (2000) "The FBI's Combined DNA Index System Program". http://www.fbi.gov/hq/lab/codis/brochure.pdf

Westervelt, Eric (1998) "DNA Database" (Audio). All Things Considered, National Public Radio. October 13. http://discover.npr.org/features/feature.jhtml?wfId=1033193

"What Every Law Enforcement Officer Should Know About DNA Evidence" (1999) National

Institute of Justice. http://www.ncjrs.org/nij/DNAbro/intro.html

Williamson, Robert and Rony Duncan (2002) Safeguards for Forensic DNA Databases. In: DNA Testing for all. *Nature* **418**: 585-586.