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DNA FINGERPRINTING

An Interactive Qualifying Project Report

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ABSTRACT

This IQP intended to show DNA fingerprinting as an emerging technology that has had a profound impact on the judicial system and on society since its first court appearance. DNA fingerprints have come a long way from conventional fingerprints. Recent advances in DNA forensics and DNA collection methods have alleviated skepticism in courts making DNA evidence more widely accepted. Despite precedence set by landmark court cases, privacy issues regarding DNA databases continue to raise ethical concerns in society.

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EXECUTIVE SUMMARY

Chapter 1 shows the reader what DNA fingerprints are, and the various ways to run them. These different kinds are explained in enough detail to give a basic understanding of their advantages and disadvantages. Explanations of DNA and DNA amplification are included in sufficient detail to provide the reader with enough knowledge to fully understand the other chapters in the report.

In Chapter 2, the forensics of DNA fingerprinting was addressed. Places where DNA evidence can be found at a crime scene are discussed, as well as how to prevent contamination. Proper methods for collection, packaging, and storage were determined. Due to recent advances in the analysis DNA technology with sensitive PCR that amplifies DNA from a crime scene, avoiding contamination becomes especially important.

Chapter 3 serves to detail the precedence set for the admission of highly technical evidence in the judicial court system. Starting with the Frye decision that set a standard for decades, it shows the evolution of the attitude of US courts towards new technologies, including DNA typing from its conception to modern day. These landmark cases are the most important in establishing legal precedence in the court system, and have helped establish national standards for DNA typing.

Chapter 4 showcases sensational court cases which have brought DNA fingerprinting into the public eye. These are high-profile cases with which most people would be at least vaguely familiar, and which remind the reader of the power of this new DNA technology.

Chapter 5 discussed the ethical issues surrounding DNA databases. DNA databases are used to match DNA profiles from crime scenes with those of previously convicted felons. The FBI's CODIS database is the largest in the world. Although such databases allow the solving of many types of crimes, privacy concerns about the storage and destruction of DNA samples, and the potential disclosure of genetic information make many people wary of giving DNA samples. Another debate ensues about whose DNA samples should be collected, convicted felons, convicted violent felons, arrested people, or everyone. Standardization of DNA laws and database procedures are needed to keep DNA databases a crucial part of law enforcement identification.

In conclusion, we agree with current Massachusetts legislation requiring adult persons convicted of crimes to provide DNA samples, but not juveniles. We also agree that the recent standardization of DNA collection and analysis techniques has helped clear the way for this powerful technology into the courtroom.

PROJECT OBJECTIVE

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

CHAPTER-1: DNA FINGERPRINT TYPES

BASICS OF DNA & THEIR FINGERPRINTS

When it comes to humans, 99% of our Deoxyribonucleic Acid, DNA, is identical to one another (Human Genome Project, 2004). We are also very close to monkeys and primates with respect to our DNA. This leaves a key 1% that is different among all humans, and this small percentage is the basis of DNA fingerprints. DNA fingerprints are very similar to conventional fingerprints as the likelihood of their being identical between individuals is much less than one in a million. Although there are about 7 people estimated to match your regular fingerprint, DNA fingerprinting can be performed on enough DNA locations to ensure no other person on the planet matches.

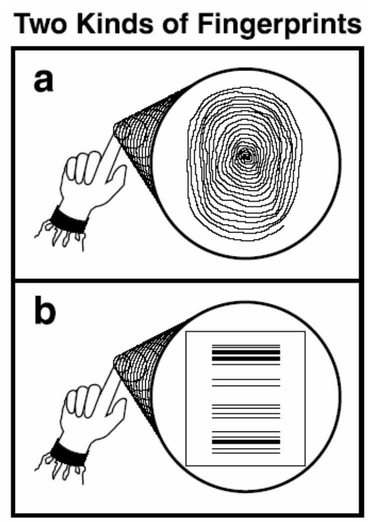

Fig 1.1, Betsch, 2004.

With conventional fingerprints nearly everything is different among people, the general type, the location of the ridges, the size of these ridges, and scars, just to name a few. With DNA fingerprints our genomic makeup is nearly identical, but the 1%

difference among us that was mentioned previously has been analyzed over the past 15 years to locate specific spots or locations, loci, that are hyper variable, or vary considerably between individuals (Schumm, 1996).

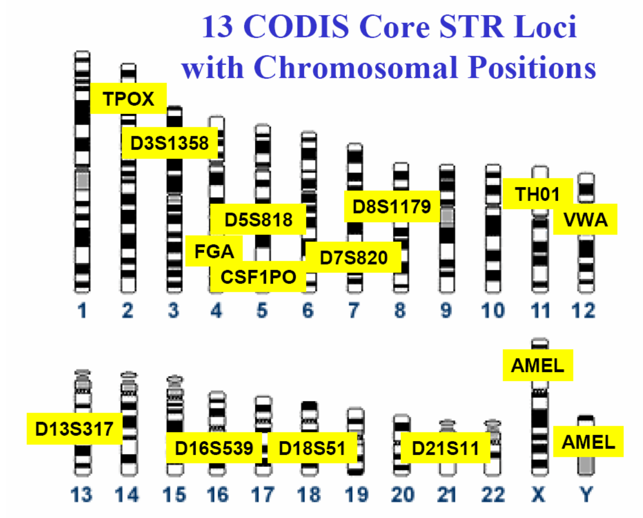

Fig 1.2. The 13 Core Loci for DNA.

Current DNA analyses when properly performed analyze 13 core loci with probabilities of a random match being one in several billion (Hallick, 2000). There are 23 chromosomes that make up the entire genomic code. Certain parts of these chromosomes contain traits such as susceptibility to skin cancer, gender, hair color, nose shape, and chin shape. The list can go on for every possible thing you can think of on a human being. Much of the information within the chromosomes is identical as the information contained must be able to “build” a human being (Human Genome Project, 2004).

This chapter will first explain the various uses of DNA fingerprints, and then explain the process of obtaining these specific DNA fingerprints. There are three main uses for DNA fingerprints, and these include Forensics, Paternity Testing, and Molecular Archeology (Biotechnology Industry Organization, 2003).

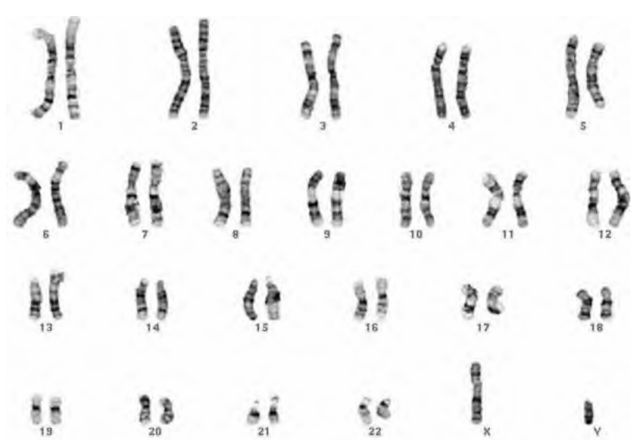

Fig 1.3. The 23 Human Chromosomes.

MAIN USES FOR DNA FINGERPRINTS

DNA FORENSICS

Forensics is the process in which DNA is collected from crime scenes and then tested against potential suspects or entries in a DNA database. The FBI has the world's largest DNA database, CODIS, that includes entries taken from previous convicted violent felons (Butler, 2004). The location of these loci can be seen in the picture shown on the previous page. In the past, forensics was done by visual inspection such as saying this hair is blonde but this suspect has brown hair so this suspect was not present at the crime scene. According to this logic then the several thousands of people with blonde hair could be at the crime scene which creates some reliability issues. The same goes with blood types, for example, if a blood sample of type AB was found with the blonde hair, this still leaves thousands of suspects. DNA can be extracted from a variety of things found at a crime scene, as will be explained in Chapter 2. From this DNA, fingerprints made up of the 13 core loci are made and then compared to suspects, victims, victims' family and friends, etc. In the test shown in Figure 1.4, the crime scene evidence matches suspect 1. Finding DNA in a forensic sample is like finding a perfect fingerprint on a newly washed window.

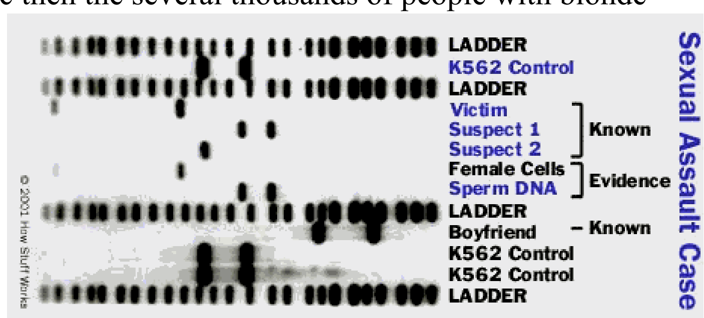

Fig 1.4. An Example of a Sexual Assult Case. Genelex, 2003.

DNA PATERNITY TESTS

Paternity testing is another key usage of DNA fingerprints. This is done by locating similarities in offspring with their biological parents (Biotechnology Industry Organization, 2003). A small scale example of these can be shown with the pennant diagram of Figure 1.5 which shows the four possibilities of offspring of a single trait from two parents. DNA paternity testing is similar to this pennant analysis to determine the probability that the offspring is in fact his or hers. Both parents have AB as the trait information, and it can be seen that there exists three possibilities, AA, AB, and BB. Basic probability tells us that if a child is AA, there is a 25% chance that the parents tested are the actual parents, 50% chance if the child is AB, and 25% chance if the child is BB. Repeating this over and over and over again on several different DNA loci the chances of accidentally labeling someone as a parent becomes extremely slim. Since the mother is AB, and the child is AB, having a father with CC is impossible. Figure 1.6 here shows an actual DNA paternity test with all possible outcomes, inclusion and exclusion.

Parents	A	B
A	AA	AB
B	BA	BB

Fig 1.5. Example of a Pennant Diagram.

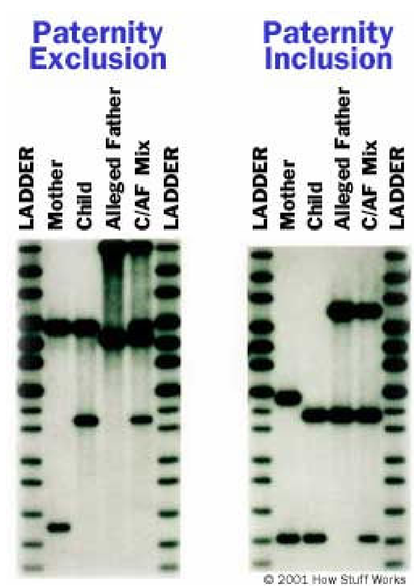

Fig 1.6. Example of a Paternity Case Solved by DNA. Genelex, 2003.

MOLECULAR ARCHEOLOGY

Molecular Archeology is very new and will soon be the future of nearly all of Archeology (Christianson, 2000). This science is completely DNA oriented and is essentially an extensive paternity test. For example, a DNA analysis of the 5000 year old mummy Otzi the iceman indicated he came from the Northern Italy. Its uses are seemingly infinite, but summarized in a few popular areas include the following: determining bloodlines/ancestors, and determining species from bones, hair, and teeth. One more recent project is using DNA to determine which sheets of the Dead Sea Scrolls are written on the hides of different animals so they can be properly pieced together. While this field is fairly new it shows great potential for the future.

DNA FINGERPRINT TYPES

Now that the three most common uses of DNA fingerprinting have been discussed, we can discuss the three main ways to run a DNA fingerprint to obtain the information which can be put towards the previously stated uses. These three processes are called Restriction Fragment Length Polymorphisms (RFLPs), Variable Number of Tandem Repeats (VNTRs), and Short Tandem Repeat Polymorphisms (STRs).

RFLP

In order to produce a RFLP fingerprint, restriction enzymes that cut up strands of DNA at certain points are introduced. By allowing the DNA to be cut up into pieces like this, the lengths of DNA that remain can be compared to find patterns among species. These patterns aren't identical even within each species; they have slight variations that can be used to tell people apart (Hill, 2004). Once the DNA has been fragmented it's not possible to just "look" at it and see the pattern, so a gel is created. A gel is a jelly like liquid/solid in which a current is put through it and the DNA separates. This DNA pattern is then transferred from the gel to a membrane to create a "blot." The blot is then hybridized to a "probe" that binds only to a specific fragment to help visualize it. The disadvantage of an RFLP analysis is that it requires a relatively large amount of DNA, and the fragments are often too large to amplify by polymerase chain reaction (PCR) (see below), so it is not commonly performed today in most forensic analyses.

VNTR

Within the unique portions of a person's DNA, certain loci vary by the number of specific repeat sequences present. The repeats are often tandem repeats (duplicates), and their numbers vary considerably between individuals, giving rise to the term variable number of tandem repeats (VNTR). The VNTR approach to DNA fingerprinting is similar to the RFLP mentioned above, in that it also uses restriction enzymes to cleave the DNA into fragments, electrophoresis through a gel to separate the fragments, and hybridization to a probe to visualize a specific band. The technique also has the same disadvantages as RFLPs since the VNTR fragments are often too long to amplify by PCR. All humans have the sections used for VNTR, but the number of repetitions is not the same. All of the different DNA sequences vary slightly. Using a larger number of these areas each person can be assigned a number or barcode through there VNTR results (Huskey, 1999). For example if two sections are quantified, a number of 3-6 can occur. These numbers represent how many repetitions of a certain sequence there are. As more and more sequences are quantified, this barcode gets longer and with the increase in variability they become very accurate. To give an idea of how accurate they are let's look at this small example; each sequence can have 2-6 repeats. With only two sequences, there exist $5^2 = 25$ possibilities. Now with five sequences, there exist $5^5 = 3,125$ possibilities. Continuing on, if there are thirteen sequences being analyzed, there exist $5^{13} = 1,220,703,125$ possibilities. The growth here is exponential so if more sequences are analyzed this number can become much greater. Another piece of information that should be remembered is that there won't always be 2-6 repeats; this range can be much greater allowing even greater possibilities.

SOUTHERN BLOT

The gel that was mentioned in both the RFLP and the VNTR sections is scientifically known as a Southern Blot. This name has nothing to do with the direction but the man who created the procedure, Edward M. Southern (Southern, 1975). The figure shown here gives a basic description of the steps involved with running this gel. First the DNA is placed in the stalls of an agarose gel, and

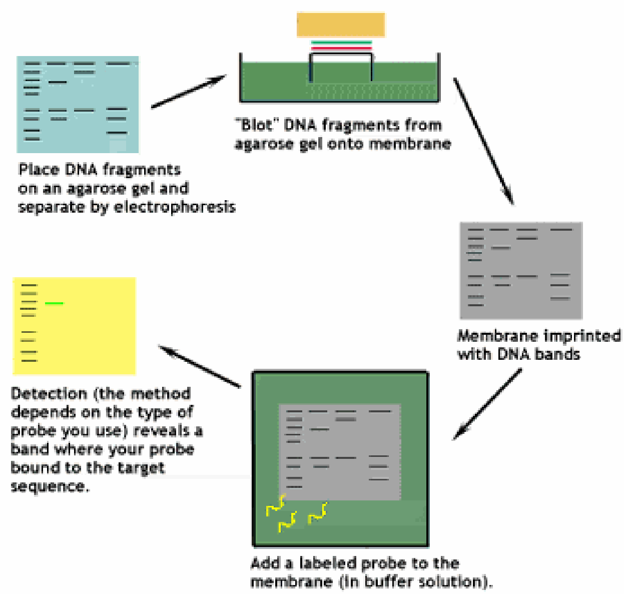

Fig 1.7. Diagram of a Southern Blot. Khalsa, 2004.

then current is placed on either side of the gel. The DNA flows to the positive anode since it is negatively charged. The smaller fragments move through the gel the fastest, so they migrate the farthest down the gel. Once fragment separation has been completed, the agarose gel is washed in an alkaline solution which breaks down the DNA down from double-stranded to single-stranded. Once this is done a membrane is introduced. Since the DNA was broken down to its single stranded form, the DNA is transferred to the membrane. From here, any number of probes can be added to visualize different sequences in the form of a "barcode."

STR

Currently the most commonly performed technique in DNA fingerprinting is the STR, or short tandem repeats. STR is extremely similar to a VNTR; the only real difference is the length of the sequence that is repeated. While VNTRs can have sizes over 1000 base pairs long, STRs are usually very short sequences, usually between 2 and 5 base pairs (Butler and Reeder, 2004). A base pair is a single location on a DNA molecule in which two nucleotide bases are hydrogen bonded with each other. There are four different bases referred to by their first letters. These are Adenine, Cytosine, Guanine, and Thymine, represented by A, C, G, and T, respectively (Hallick, 2000). The patterns of these four bases

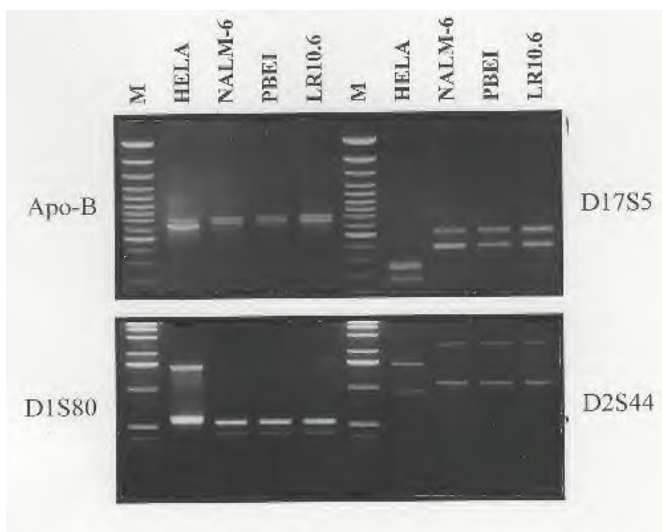

Fig 1.8. STR Analysis. DZMZ, 2004

create specific sequences which are measured in DNA fingerprinting. One common sequence used in STRs is from the D7S280 locus. In D7S280, the sequence "GATA" is repeated. This particular sequence is known to show between 6 and 15 tandem repeats.

The main reason STRs are the favorite method of DNA analysis is the fragments are short enough to be amplified by PCR (see below). This allows two time consuming steps, transfer to a membrane, and hybridization to a probe, to be eliminated. PCR primers are designed to flank a specific STR site, and then the PCR reaction is run. The length of the amplified STR fragment is simply determined by column chromatography, which is much faster than electrophoresis. And most importantly, the use of PCR allows trace amounts of DNA at a crime scene to be amplified for analysis. So because STR analysis is faster, it allows a far greater number of samples to be run. And because it is more sensitive (using PCR), it allows the analysis of samples not amenable to RFLP or VNTR.

Remembering the example from VNTRs with a range from 2-6 repeats gives us over 1 billion possibilities, the range from 6-15 is nearly double that, giving us over 2,541,865,828,329, that's 2.5 trillion possible combinations. Some combinations will be so unique that it only happens in 1 in 7.7 quadrillion peo

Fig 1.8, DZMZ, 2004

PCR

Polymerase chain reaction (PCR) is a technique used to amplify short stretches of a DNA molecule. Short DNA primers are designed to flank both sides of an STR region. The primers are made synthetically. First the DNA sample is denatured to single strands. Then the temperature is cooled to allow the DNA primers to attach to the DNA. Taq polymerase which is active at elevated temperatures is used to synthesize new strands of DNA from the primers. Then the DNA is denatured again, and the cycle repeated 30 to 50 times. This increase is done very rapidly, usually within a few hours, and often increases by over one million fold (Schumm, 1996). As can be seen in the figure shown here, there is an exponential increase in the number of copies of the original DNA region. By being able to multiply the amount of DNA in a specific sample, DNA can be collected in extremely small quantities and then copied a few million times to get the necessary amount for an STR analysis.

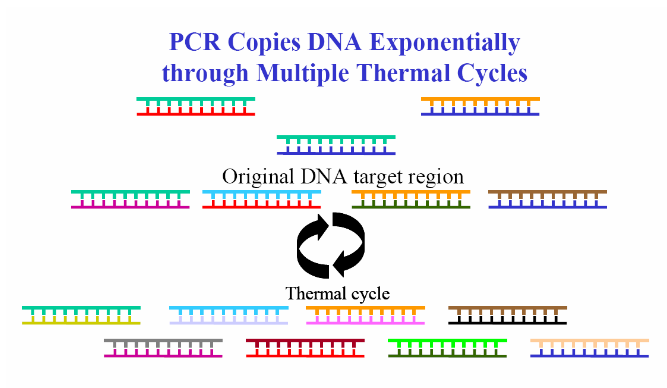

Fig 1.9. Diagram of PCR. Butler, 2004.

CHAPTER-2: DNA FORENSICS

Advances in the Field of Forensics

Maybe, just maybe, the DNA fingerprint found at the gruesome murder scene matches more than one suspect. How can the courts be certain that the person sitting on the defense side actually committed the crime? Can the defendant be found guilty without a doubt based on a tiny blood stain? What are the odds that the wrong person is being prosecuted? With these questions in the mind of jurors across the country in the 1980s, complicated by a lack of standardized methods for collecting and analyzing DNA, DNA evidence was having a difficult time of being accepted in the courts. Complex statistical formulas and skepticism created further doubt in the jurors. But recent advances have been made in a field that heavily relies on predictions; these predictions have become more accurate and reliable as the databases they are built on have grown in size (Meeker-O'Connell, 2005).

Is that tiny blood stain enough to convict someone? Using the relatively new technique of Polymerase Chain Reaction (PCR), the size of the DNA sample is no longer a factor. Requiring only a tiny specific DNA sequence, PCR can copy it within hours and the forensic analysis can began shortly after (Meeker-O'Connell, 2005). How can we be sure that the DNA evidence identified the right person? Scary mathematical formulas have been reduced to figures that indicate that an incorrect match is a "very improbable event" ("The Future of Forensic DNA Testing," 2000). How improbable? A person who is not a twin has 2,000 times more of a chance winning the Publisher's Clearinghouse Sweepstakes than having his or her DNA fingerprint match someone else's (Meeker-O'Connell, 2005). U.S. courts have acknowledged the use of the profile probability—or sometimes referred to as the traditional procedure due to its simplicity and its use dating back to the first DNA court cases—in which a DNA profile is assigned a probability from the appropriate population. Once a suspect whose DNA profile matches the one in question is found, and the probability is a small fraction, the culprit has been identified. The greater the number of locations or loci analyzed on the DNA molecule, the lesser the chance of an incorrect match. The current standardized protocol, established by the Federal Bureau of Investigation (FBI), analyzes 13 core loci. After determining that the probability of a match between two randomly selected people is 1 in 6×10^{14} using the 13 Short Tandem Repeats (STR) loci method, the idea of making an incorrect match diminishes, and using DNA evidence in the courtroom has become a more accepted practice ("The Future of Forensic DNA Testing," 2000).

Other recent advances include DNA databases. Countries such as Britain, Australia, and Japan, as well as the United States, have compiled extensive DNA profiles for hundreds of thousands of individuals convicted of violent felonies who were required to give a DNA sample (Meeker-O'Connell, 2005). The more individual profiles in a database, the easier it is to be mathematically sure the match is correct. Another advance is the standardization of forensic lab procedures, which will be outlined later in this chapter. This includes proper procedures for handling, packaging, and analyzing DNA evidence.

DNA testing, when done correctly, presents evidence that would not have known otherwise. But humans are the ones that do the testing, and humans make mistakes. The idea that DNA evidence is infallible is unrealistic. "Any scientific procedure that involves human execution and judgment has some probability of error" (ACLU, 2005). Though it is not perfect, DNA testing is improving. New more accurate and sensitive techniques, the inclusion of positive and negative controls in the analysis, better statistical information, along with better training for laboratory workers, better working conditions and continuous DNA research, have caused the reluctance toward DNA evidence to diminish. Along with other advances in the forensics field, DNA evidence is being used to convict murders and exonerate the innocent.

Sources of DNA at a Crime Scene

There are two types of DNA used in forensic analysis: nuclear DNA (nDNA) and mitochondrial DNA (mtDNA). Nuclear DNA can be found in blood, semen, saliva, body tissues, and hair roots. Mitochondrial DNA is found in naturally shed hairs, hair fragments, bones and teeth ("Handbook of Forensic Services," 1999). Besides identification, mtDNA is used in tracing ancestry through the female line; mtDNA is transmitted by the egg and not the sperm, so a mother gives her mtDNA to all her children ("The Future of Forensic DNA Testing," 2000). Charred remains, not fit for chromosomal DNA analysis, can be identified by mtDNA.

Figure 1: You can find testable DNA just about anywhere, as shown by the red spots on the Bascom (Hall) strangler, caught in the act.
From: Dieter, "Short, Ironic History", 2001.

The strangler in Figure 1 is covered in red dots, dots that signify the presence of DNA. Though the offender may be convinced that he or she left no noticeable trace behind at the crime scene, there may be evidence everywhere but invisible to the eye. Stopping to have a drink of water from the kitchen sink of the house he is robbing, a burglar unknowingly provides evidence—saliva and sweat—that can be used against him. The incriminating evidence is there; the trick is to find it. Table 1 offers possible places where DNA can be found.

Evidence	Possible Location of DNA on the Evidence	Source of DNA
Baseball bat or similar weapon	Handle, end	Sweat, skin, blood, tissue
Hat, bandanna, or mask	Inside	Sweat, hair, dandruff
Eyeglasses	Nose or ear pieces, lens	Sweat, skin
Facial tissue, cotton swab	Surface area	Mucus, blood, sweat, semen, ear wax
Dirty laundry	Surface area	Blood, sweat, semen
Toothpick	Tips	Saliva
Used cigarette	Cigarette butt	Saliva
Stamp or envelope	Licked area	Saliva
Tape or ligature	Inside/outside surface	Skin, sweat
Bottle, can, or glass	Sides, mouthpieces	Saliva, sweat
Used condom	Inside/outside surface	Semen, vaginal or rectal cells
Blanket, pillow, sheet	Surface area	Sweat, hair, semen, rectal cells
"through and through" bullet	Outside surface	Blood, tissue
Bite mark	Person's skin or clothing	Saliva
Fingernail, partial fingernail	Scrapings	Blood, sweat, tissue

Table 1: Sources of DNA
From: National Institute of Justice, 1999

Another source of DNA is a deceased individual. In an effort to either identify the deceased, or find incriminating DNA evidence about the offender, a search of the body is necessary. Deceased individuals who are decomposed can still provide DNA. The most suitable source of DNA is a pulled hair with the root. The root contains tissue which in turns contains DNA and can be analyzed. Bones, such as ribs and any long bones, can also be used, as well as teeth. Muscle tissue, if any, can be used and the deeper it is the better. Finally, any personal property belonging to the victim can be used such as a toothbrush or a hairbrush (Kramer). Recently-deceased individuals or individuals with early signs of decomposition still have DNA. Blood can be collected into vacutainers and a cheek swab (buccal swab) can also be preformed using a cotton swab. In addition to these samples, pulled hairs, bones, muscle tissue, and personal property can also be used ("DNA Evidence Collection at Crime Scene").

Evidence can be hidden anywhere. Investigators have to look everywhere; this includes places where DNA evidence might have been. How can investigators be certain that a suspicious stain on the carpet, with no visible blood present, was not an ill attempt by the offender to get rid of evidence? One technique uses luminol, a chemical compound that will glow bluish-green in the presence of iron in the hemoglobin of blood (Harris, 1998). However, bleach also makes luminol glow. And though it might lead to traces of blood, luminol also has the potential of destroying other evidence. But it can be used as a last resort to find all sources of DNA at a crime scene.

Figure 2: A bloody footprint is revealed with the use of luminol.
From: Harris, "How Luminol Works," 1998.

Prevention of DNA Contamination

As we learned in the O.J. case, which is discussed in Chapter-4, contaminated DNA evidence or potentially contaminated DNA evidence can result in a loss of confidence in the DNA analysis. Once contaminated, the precious amounts of DNA are wasted and no longer able to be used. "If DNA evidence is not properly documented, collected, packaged, and preserved, it will not meet the legal and scientific requirements for admissibility in a court of law" ("Handbook of Forensic Services," 1999).

Beginning with clearly identifying the date, time, and description of the evidence so that the origin of the evidence is clear and can not be questioned, the collector, and all subsequent handlers of the DNA evidence, must avoid contamination ("Handbook of Forensic Services," 1999). The possibility of contamination is high for small volume stains as well as old and degraded samples (Spear, 2004). So put on your latex gloves and your face masks and get ready to collect some DNA evidence.

The most effective and logical step in the prevention of contamination is to ensure that there is no contact between DNA samples or with any other surface at the crime scene. The proper procedure is to collect and package each stain of evidence separately. The tools—tweezers, scissors, box cutters, scrapers—used during this process should be cleaned with distilled water and thoroughly dried with paper tissue. Bleaching the tools is unnecessary and also a hazard; bleach can destroy biological evidence (Spear, 2004). Talking and coughing over evidence is another way to contaminate and ruin the DNA evidence; wearing a mask is highly advised. Limiting the number of people who have access to the crime scene is another step in avoiding contamination by not giving too many people the opportunity to touch, remove, and/or destroy evidence ("Crime Scene Investigation," 2000).

Once a person knows how to act around the evidence, it is time to pack it up. Storage of DNA evidence is critical: "the more the evidence retains its original integrity until it reaches the laboratory, the greater the possibility of conducting useful examinations" ("Handbook of Forensic Services," 1999).

For the storage of all biological evidence, do not use plastic. Paper bags and envelopes should be used instead due to the fact that it is porous and will allow air inside, permitting wet evidence to dry on the way to the lab ("Handbook of Forensic Services," 1999). Wet samples can degrade quickly.

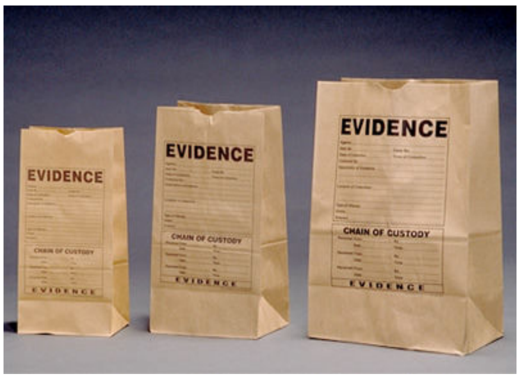

Figure 1: Paper evidence bags
Used for larger samples of evidence
From: Evidence Collection and Protection, Inc., 1998.

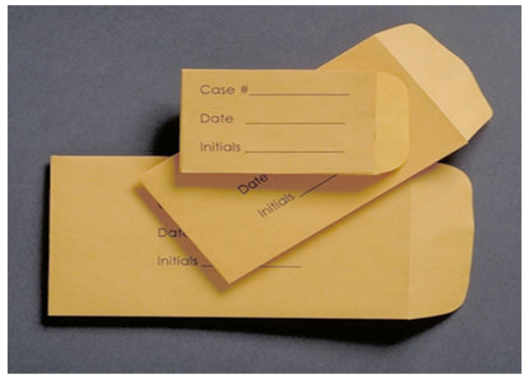

Figure 2: Paper evidence Envelopes
Used for small samples of evidence
From: Evidence Collection and Protection, Inc., 1998.

However, plastic containers are only advisable in the case of packaging tissue samples, such as skeletal muscle, and the storage should not last longer than 2 hours prior to DNA extraction (Schiro, 2001). Figure 3 shows acceptable plastic packaging.

Figure 3: Plastic Containers
Can be used for packaging tissue samples
From: Evidence Collection and Protection, Inc., 1998.

Figure 4: EDTA Vacutainers
Contains an anticoagulant for blood storage
From: Becton, Dickinson and Company, 2005.

Blood should be collected in purple top vacutainers containing ethylenediamine-tetraacetic acid (EDTA), an anticoagulant. Figure 4 shows EDTA vacutainers. EDTA prevents nuclease activity that breaks down the DNA; it safeguards the DNA for analysis (Spear, 2004). Blood should not be frozen but refrigerated. For bloodstains and semen stains that are wet, absorption onto a clean cotton swab and letting it air-dry is the appropriate protocol; once the swab or piece of cloth is dry, package in a paper envelope. Dry stains on small objects should be not be disturbed; the whole thing can go to the lab. However, if the stain is on something large, absorb the stain with a clean cotton cloth or swab using distilled water. Air-dry the swabs or cloths as best as possible and package in paper envelopes ("Handbook of Forensic Services," 1999). Obtaining control samples is also a requirement ("Crime Scene Investigation," 2000). Collecting cotton swabs or cloths of the area around the evidence is important as a negative control in determining if there is contamination.

Preventing contamination in the laboratory is the next worry for the handlers of the DNA evidence. The FBI has established standards for laboratories. To minimize contamination in the laboratory, the facility should have "controlled and limited" in and out access, all the steps leading up to PCR should be done individually, do not multitask, analyzed and unanalyzed DNA is to be kept apart, and the facility is to be properly cleaned and decontaminated once the analysis is complete ("Standards for Forensic DNA Testing Labs").

Prevention of DNA Degradation

Using distilled water is a double-edged sword. While aiding in the removal of precious DNA samples from walls and chairs, water is the main source of DNA degradation. Adding more water to a sample already diluted by distilled water will cause bacterial growth and the destruction of DNA (Spear, 2004). Paper packaging containers prevent degradation by allowing the samples to air dry. Plastic containers trap the moisture of wet evidence samples, creating an environment for microorganisms to grow and destroy the DNA evidence (Schiro, 2001). Warm, humid surroundings all contribute to the degradation of DNA. Other factors that are a source of DNA degradation are time, chemical exposure, and light ("Physical Evidence," 2005). Therefore storage of evidence in the lab is just as important as packaging it at the crime scene.

A recent retest of 49 DNA cases produced inconclusive results; all the DNA evidence was less than 8 years old (ACLU, 2005). Critics view degradation as one of the many things wrong with DNA fingerprinting; the invasion of privacy, discussed in Chapter-5, is another concern. Preventative measures taken to control degradation are necessary. Biological samples should be stored in a dry and cold environment ("Physical Evidence," 2005). Leather and denim contain compounds that damage DNA samples and make PCR reactions difficult; the removal of evidence from such surfaces as leather insures that the evidence will maintain its integrity (Spear, 2004). For short term storage, maintaining room temperature will suffice and preserve the samples. Blood should be stored in a refrigerator. Long term storage should be done in a freezer at temperatures ranging from 4ºC to -20ºC ("Physical Evidence," 2005). Liquid blood samples are turned in bloodstains and frozen; clothing stained with DNA samples is better protected in non-defrost cycle freezers (Spear, 2004). The DNA itself "should be kept as concentrated as possible, stored in TE buffer, and held frozen in airtight tubes" (Spear, 2004). A TE buffer is a Tris-HCl, and EDTA solution used to hinder DNase activity, thus slowing down degradation ("TE Buffer pH 7.0 & 8.0"). Extracted DNA samples should be kept at -70ºC ("Physical Evidence," 2005).

Everyone handling the DNA evidence must make the effort to follow all the guidelines and standards for the proper crime scene protocol and forensic laboratory procedures. Taking all the necessary precautionary measures while collecting, packaging, storing, and analyzing the DNA only strengthens the DNA evidence's integrity. Prevention of contamination and degradation will ensure that the DNA evidence is acceptable in a court of law.

CHAPTER-3: LANDMARK DNA COURT CASES

Complex technical information has long been an important factor in legal proceedings. As forensic science advances, the legal system must come up with new ways of treating these new advances in science. Typically as the new procedures become more standardized, and generally accepted, they will be admissible as evidence in a court of law. Among these types of complex technical procedures is DNA fingerprinting. DNA fingerprinting, like many other procedures of its sort, has been refuted, touted, and everything else since it was first announced by Sir Alec Jeffreys in 1985 (Wikipedia, 2005).

DNA fingerprinting is the collective term for the procedures used to identify a specific person using nothing but their DNA. In a court case, the evidence would likely be saliva, blood, semen, or another bodily fluid collected from the crime scene. This evidence would be examined in a laboratory to extract the DNA sequence from it. The individual(s) in question would then provide a sample of their own DNA, and the sample from the crime scene would be checked against the other collected samples. If the DNA at the crime scene is found to be the same as the DNA provided by a suspect, then it proves the suspect was present at the scene, and adds to the overall evidence that the suspect may very well be guilty of the crime.

The problem with DNA evidence, however, is its admissibility in court. While it is largely respected now, this has not always been the case. There are always standards that any new technical procedure must meet, and these standards have changed over the years to ensure that they are reliable and accurate.

The end goal of any legal proceeding is that justice is served for all parties concerned. In keeping with this ideal, it is understandable that for any evidence to be admitted there must be no doubts about it being technically sound. If this is not the case, a guilty man may walk or an innocent man may be convicted solely because of shoddy techniques regarding the admissibility of such highly technical evidence. As we discussed in Chapter-2, appropriate controls must be run with the DNA to rule out contamination and degradation. If not for all of these standards for admissibility, there would be a much higher possibility that evidence admitted into court is erroneous and ultimately detrimental to the justice system. There have been many court cases in the past which have served to provide a standard for accepting DNA evidence (and technical evidence in general) in the judicial system (discussed below). In these cases, evidence has been accepted or rejected based on what was perceived to be its intrinsic validity. These cases have established a precedent for the admissibility of technical evidence in the future. This precedence will continue to conform and acclimate itself to the every changing scientific world we live in as more and more cases continue to mold and modify it little by little.

Frye v US, 1923

An old example of set precedence which still has relevance today is known as the Frye Standard. Set in 1923 during *Frye v. United States* in the U.S. Court of Appeals for the District of Columbia when reviewing the admissibility for evidence from a primitive polygraph test, this standard attempted to clarify the point at which an experimental procedure becomes an accepted practice (Fiatal, 1989). The Frye standard states that in order for an expert testimony to be admissible in court, the underlying procedure must be generally accepted by experts in the relevant field. What constitutes "general acceptance" became a point of some contention over subsequent decades, and the Frye Standard has remained controversial (Wikipedia, 2005).

In the case of *Frye v. The United States*, the prosecution administered what was called a systolic blood pressure deception test (lie detector test) in order to try and prove that the defendant was lying in his testimony. This test used the change in blood pressure caused by emotions to try and determine whether or not the subject was lying. Scientific experiments at the time had claimed that if a person is lying it could be discovered by the test because their systolic blood pressure would rise because of guilt of a crime, the conscious act of lying, and general fear about the test and being caught. When administered to Frye, he passed the test, so the defense counsel wanted to include the results in the trial (Frye, 1923).

This lie detector procedure was highly technical, and not understood by the average American at the time. Therefore, the jury would have a hard time understanding all the technical information presented to them. In light of this, counsel for the defendant called the scientist that administered the test as an expert witness. The court saw it necessary for an expert to inform the jury in some of the workings of the procedure in order for them to make an informed and correct judgment. If the jury was ignorant about how the results of the systolic blood pressure deception test were obtained, and what they meant, then true justice could not be served. After the expert testimony, the test was found to be not admissible as it did not have the general acceptance of psychologists and psychotherapists at the time. The procedure was found to be too experimental and not yet ready to be admitted as evidence in this case. It had been decided that the systolic blood pressure deception test and other complex technical evidence must not be admitted as evidence until they were used as a common practice, as well as having the general acceptance of experts in its specific field (Frye, 1923).

The Frye Standard, as it has come to be known as, was stated by the justices serving on the court as shown below in 1923 as a standard by which to rate the admissibility of technical expert testimony:

> *Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential forces of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle of 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* (Fiatal, 1989).

Not all the states adopted the Frye Standard due to the difficulty of establishing the "general acceptance" of any procedure in the scientific community. It was loosely worded, and it became the burden of a party trying to use such expert testimony to prove that it adhered to the Frye Standard. In order to do so the relevant field would first have to be identified. Then, the counsel would have to refer to journals, professional societies, media, and other sources in order to show that the practice had indeed received general acceptance in the relevant field. The difficulty understandably arose when having to make the distinction between the dissention of views among experts in the field, and what exactly constituted general acceptance (Fiatal, 1989).

DNA fingerprinting has since been found to hold up to the Frye standard and other standards formed afterwards. The technology used has widespread approval and has proven to be a very reliable way to identify. It has been said that DNA is the most accurate identifier of an individual that we have available with current technology. It is because of this that DNA evidence is so valuable in a court of law.

As technology advances, and becomes even more technical, it becomes necessary to update the standards of admissibility so they can keep up with the changing times. Since DNA fingerprinting is a much more involved, and complicated process than the systolic blood pressure test; it was appropriate for the Frye Standard to be upgraded in order to stay abreast of the ever changing technological world. In 1989, Judge Scheindlin of the Superior Court of Bronx County, New York updated the Frye Standard with a three-pronged system by which to evaluate technical evidence. The three pronged system is based on the outcome of the People v Castro case (Patton, 1990).

People v Castro, 1987

In 1987, police in the Bronx detained Jose Castro in part of a murder investigation when they noticed a bloodstain on his watch. DNA analysis was performed by a Lifecodes laboratory and they claimed that the blood on the watched matched to blood of the victim's, but the court found that the laboratory had not followed practices which were seen by the court and leading experts in the field to be necessary to produce reliable results. As a result, the evidence was not admitted. The court believed that the general use of DNA evidence is acceptable, however in this case the procedure used was not reliable enough to admit the evidence in court. The revision to the Frye Standard stressed the need for DNA fingerprinting or other techniques to adhere to a specific procedure in order to yield accurate, reliable, and reproducible results. This is very important as a mistake in the procedure could conceivably cause an error in the results. Justice Scheindlin did not want any possibility of invalid or erroneous evidence tainting the mind of the jury as this could irrevocably tip the scales in the favor of a verdict which might not have been reached with scientifically-sound and accurate evidence. The revision to update the Frye Standard for DNA evidence by Justice Scheindlin reads as follows:

> *Prong I: Is there a theory which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results?*
>
> *Prong II: Are there techniques or experiments that currently exist that are capable of producing reliable results in DNA identification and which are generally accepted in the scientific community?*
>
> *Prong III: Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case* (Patton, 1990)*?*

The revised standard places new emphasis on the techniques used in DNA fingerprinting, and would apply to any new technology. It ensures that the laboratory will adhere to the standards and procedures approved by the scientific community when conducting their experiments. This means that any DNA fingerprinting evidence to be admitted will have to be carefully and methodically produced by the most widely accepted of procedures. The Castro revision, just as the original Frye Standard, is an attempt to be sure that true justice will be served, and that juries will not be confused or distracted by confusing technical evidence that may or may not be valid (Patton, 1990).

In *New York v. Castro*, Lifecodes was found to not have followed accepted procedures while they were performing the DNA fingerprinting. Because of this, the evidence was not admitted in this particular case. The new revision of the Frye Standard, however, set the stage for DNA evidence to be used in the future and showed that DNA fingerprinting had indeed achieved a general acceptance as required by the Frye Standard. Over time, the technique would become more and more reliable, and play larger and larger roles in court cases.

Statutes of Limitations and DNA Evidence

Statues of limitations are laws that prevent the prosecution of a suspect for a crime after a certain amount of time has passed, typically several years. When these laws were passed, they served as a safeguard to protect innocent people from being convicted of crimes which they did not commit. After such an extreme passage of time, the memories of witnesses, and the defendant will naturally fade. For example, a man robs a convenience store and gets away. Twenty years later, a man is charged with the crime. It would be very hard to determine with any certainty whether or not the accused man was indeed the one robbing the store because the memories of the involved parties would naturally have faded. If an eyewitness saw the robbery, they can not be certain if the accused really did rob the store because their memory is not as clear as it was several years ago. It is much harder to be so certain about something when removed so much from the event. Also, if prompted for an alibi, it is very likely that the defendant would have no idea what he was doing at that particular time. With the exception of work, vacation, or another documented alibi it would be hard to prove things one way or another.

In recent years, these statutes of limitations are falling under constant scrutiny. Especially in the area of violent crimes such as murder and rape, the laws concerning statues of limitations are being questioned and revised. This is made possible partly due to DNA forensic evidence. Since DNA is a code that is uniform and unchanging for each and every person, the evidence will not expire or be at all invalidated by the passage of time, like say an eyewitness testimony, the statutes of limitations become more of an obstacle to justice rather than a protector of it with the prevalence of DNA technology today. In recent years, DNA evidence has been used to push these statutes of limitations to their limits and has led to widespread debate over the modern applicability of the statutes of limitations laws in certain spheres such as violent crimes and sexual assault.

In August of 1994, a man broke into the apartment of a young woman and threatened her life unless she gave him what he wanted. The crime was one of several similar crimes in the area. The man would break into young women's apartments and conduct himself in a similar manner each time, usually pushing a pillow over the woman's face to conceal his identity. Six years later, still plagued by the event, this young woman and many others like her were about to lose any hope to possibly prosecuting their assailant. The statute of limitations was about to pass, and as of yet the authorities had been unable to find the person guilty of the crime. What the police did was file a "John Doe" warrant for the man that committed the crime six years ago. Instead of describing a suspect by name, or by physical description, the police filed a warrant for the man with the same DNA sequence as was found and collected as evidence from the crime scenes (See Figure 1). Such a warrant would allow the police to cross reference DNA databases of criminals and see if they can find a match to that found at the scene in the young woman's apartment in 1994. This would allow them to charge the man with these additional crimes and make sure that he gets sentenced for all his crimes (Delsohn, 2001).

THE PEOPLE OF THE STATE OF CALIFORNIA,

vs.

JOHN DOE ,unknown male with Short Tandem Repeat (STR) Deoxyribonucleic Acid (DNA) Profile at the following Genetic Locations, using the COfiler and Profiler Plus Polymerase Chain Reaction (PCR) amplifications kits: D3S1358 (15,15), D16S539 (9,10), THO1(7,7), TPOX (6,9), CSF1PO (10,11), D7S820 (8,11), vWa (18,19), FGA (22,24), D8S1179 (12,15), D21S11 (28,28), D18S51 (20,20), D5S818 (8,13), D13S317 (10,11), with said Genetic Profile being unique, occurring in approximately 1 in 21 sextillion of the Caucasian population, 1 in 650 quadrillion of the African American population, 1in 420 sextillion of the Hispanic population

Figure 1: The John Doe warrant filed by Sacramento police in August 2000 which identified a suspect by DNA sequence instead of by name or physical description. (Delsohn, 2001)

Three weeks after the warrant was filed, the DNA was matched to a sample taken from Paul Eugene Robinson in 1998; who had spent time in jail for violating his parole after a string of robberies. He was found prowling and loitering around private property. Blood and saliva samples were taken because of a conviction of spousal abuse. Investigators now believe he might have been looking for his next victim but at the time there was no suspicion of any sexual assaults. He had been freed after serving part of his sentence for violating his parole. Authorities revised the John Doe warrant to detail Mr. Robinson by name and by physical description. When police tried to locate him, the man fled but was quickly apprehended. DNA evidence had led to the apprehension of a suspect in a string of unsolved crimes (Delsohn, 2001).

When brought to trial, the judge had to rule on the matter of whether or not the warrant was valid and about the passing of the statute of limitations. The problem was that California State law requires that a warrant contain descriptions on the front page so that the wrong man was not arrested. The defense had an issue that the front of the warrant was no more descriptive than "John Doe, Black Male". The genetic information was too long to type into the computer program used to generate warrants so the information was included in additional paperwork and in electronic comments in the electronic version, but was not printed out on the physical warrant. After deliberation, the presiding justice ruled that warrants are used to arrest those suspected of guilt, while preventing the wrong person from being arrested, and that in this case there was enough information available to authorities to prevent this from happening (Delsohn, 2001).

In this case, we see that DNA fingerprinting is an extremely valuable tool. If not for the use of the John Doe warrant, this criminal would never have been brought to trial for his heinous crimes. This goes to show that DNA forensic evidence has been and will continue to be a great asset to public prosecutors in these sorts of investigations.

Conclusions

The issue of acceptable use of DNA procedures and other highly technical evidence in court cases will continue to be one of great importance. As technology continues to advance, these standards of precedence will continue to change and adapt to keep up with the times. As we saw in People v Castro, the old Frye Standard required an update in order to better serve the demands of a legal climate in which DNA evidence was quickly becoming more and more accepted and used. In People v. Paul Eugene Robinson, we saw that DNA evidence was used to circumvent the laws of the statute of limitations in California. As genetic technology advances, statues of limitations are being challenged all over the country. Eventually this technology will enable the prosecution of criminals justly for violent rapes and homicides regardless of the amount of time elapsed since the crime took place. Taking these rapists and murderers off our streets will make our world a safer place, as well as deter some potential would-be wrong-doers from committing such a crime in the first place.

DNA evidence is great tool used by prosecutions to keep criminals off our streets and to make our world a safer place. It holds a place in the long line of complex technical techniques used to furnish evidence to a trial, and will most assuredly not be the last. As these technologies continue to advance, so must the standards for admissibility as detailed above. With each new technology, the rules must be adapted and tailored to ensure that only the most accurate and correct evidence is committed in a trial. As we have seen this happen in the past in such cases as Frye and Castro, it will continue to happen in the future with newer technological practices as they are invented and developed. These rules governing admissibility of evidence serve to ensure that justice can be served to the best of our society's ability, and that our world can continue to be a reasonable safe and just place to live.

CHAPTER-4: SENSATIONAL DNA COURT CASES

The Boston Strangler

June 14th, 1962 marked the beginning of a new era of terror for Boston-area women. On that evening, Anna Slesers was found brutally murdered and sexually-assaulted on the floor of her bathroom. Her son went to look for her after she would not respond to his knocking on the door. He entered the ransacked apartment to find her body in the same way that police would find it; starkly exposed and apparently strangled with the cord from her own bathrobe (Bardsley and Bell, 2005).

The gruesome circumstances, methods, and the victim of this crime would come to serve as a modus operandi for the man (or men) responsible for several similar crimes over the next 18 months. Local women lived in a constant state of fear of the unknown killer. Many became very suspicious of strangers (some even of friends) and took additional measures to try and make their homes more secure and safe (see Figure 1). Despite the growing collective cautiousness, the killings continued. The victims still seemed to let the murderer into their homes more often than not, so likely they trusted his appearance.

Every few months, another string of similar crimes would be committed on more women. The perpetrator consistently evaded the authorities and could not be positively identified by any eyewitnesses. There was little in the way of constructive or consistent evidence left at any of the crime scenes; at least not enough for police to prosecute any suspects. The longer the murderer went undetected, the more cautious the Boston-area women grew (Bardsley and Bell, 2005).

Figure 1: Woman sets a homemade alarm
for her door (Bardsley and Bell, 2005).

On December 5th, 1962 the next victim in this era of terror was killed. Twenty-one-year-old Sophie Clark, like many others, had become increasingly wary of visitors. She had installed a second lock on her apartment door. Despite the extra precautions, her body was found dead; sexually-assaulted and strangled with three of her nylons. Oddly enough, while there were signs of a struggle, there was no damage to any of the doors, locks, or windows. Apparently Sophie had let her killer into the apartment. This seemed very odd for a woman who would routinely interrogate friends through the door before opening it for them. An upstairs neighbor in the building had told police that a man had come to her door saying that he was sent by the superintendent to do some painting in the apartment. The man made a forward comment to the woman and she informed him that her husband was in the next room. The man grew annoyed and quickly left on a shoddy excuse. It is thought that this man might have been the Boston Strangler. Could the same line about painting have fooled Sophie Clark downstairs (Bardsley and Bell, 2005)?

A little over a year later, the Boston Strangler decided to taunt the authorities. On January 4th, 1964, the body of yet another victim was found. Mary Sullivan, 19, was found by her roommates; brutalized and murdered in a similar fashion to the other alleged victims. Propped against her foot was a "Happy New Years" card (Bardsley and Bell, 2005).

This startling scene seemed to be the proverbial "last straw" for Massachusetts Attorney General Edward Brooke. He made the case a first priority and formed a special squad of investigators to work on the case. Full-time staff was exclusively devoted to the Boston Strangler case. The task force began by appropriating all the information it could from the five police precincts involved in the case. It was thought that this singular entity could conduct a more comprehensive, more objective, and more empirical investigation of the matter than could several rival police precincts which routinely withheld evidence from each other. Later, in March, Governor Peabody announced a $10,000 reward for information leading to the arrest of the person(s) responsible for these murders. The Commonwealth of Massachusetts was making great efforts to put an end to these slayings (Bardsley and Bell, 2005).

A lengthly investigation ensued, however no suspects could be proven to be the killer. Finally, in April in 1965, a man came forward and confessed to the slayings.

Albert DeSalvo (see Figure 2) confessed to the 11 Boston Strangler murders, as well as two other murders that were previously thought unrelated. Up until this point, DeSalvo was not on the list of suspects, but police were quickly convinced because he was said to have known details about the crimes and the crime scenes that supposedly only the killer could have known:

> *"Details piled upon details as DeSalvo recalled the career of the Strangler, murder by murder. He knew there was a notebook under the bed of victim number eight, Beverly Samans; he knew that Christmas bells were attached to Patricia Bissette's door. He drew accurate floor plans of the victims' apartments. He said he'd taken a raincoat from Anna Slesers's apartment to wear over his T-shirt because he had taken off his bloodstained shirt and jacket. Detectives found that Mrs. Slesers had bought two identical coats and had given one to a relative. They showed the duplicate to DeSalvo, along with fourteen other raincoats tailored in different styles. DeSalvo picked the right one* (Bardsley and Bell, 2005)*."*

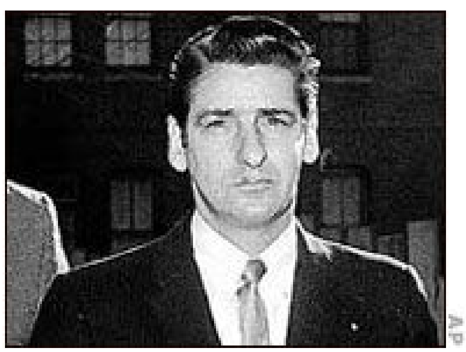

Figure 2: Albert DeSalvo
(Bardsley and Bell, 2005).

Family, friends, and acquaintances of Albert DeSalvo were shocked at his confession. They believed it to be a complete lie and a fabrication. DeSalvo was known to be a part-time petty thief, but no one believed that he would be capable of such brutal acts against these 13 women. Even the police who had come to know him from all his arrests for robberies didn't believe that he was the real Boston Strangler. DeSalvo's robberies were dubbed the “Green Man” attacks, and DeSalvo was worried that he would be spending the rest of his life in jail for these offenses. It is now thought that DeSalvo confessed to the Boston Strangler crimes because he felt that he would be incarcerated for the rest of his life on the Green Man charges. Seemingly, he believed his family would suffer because he would be unable to earn a wage and provide for them while in prison. When questioned by his attorney about what he hoped to achieve with his confession, DeSalvo replied:

> *"I know I’m going to have to spend the rest of my life locked up somewhere. I just hope it’s a hospital, and not a hole like this [Bridgewater]. But if I could tell my story to somebody who could write it, maybe I could make some money for my family* (Bardsley and Bell, 2005)*."*

DeSalvo was about to stand trial. As authorities only had a confession, and no physical evidence to prove that DeSalvo committed the Boston Strangler crimes, he was only tried on the Green Man charges (Weubben, 2001). DeSalvo’s attorney, the famous F. Lee Bailey, hoped that he could use the confession to the murders as proof that DeSalvo was insane, so that he could both avoid execution for the murders and be sent to a psychiatric hospital for care. He hoped that DeSalvo might help authorities learn what made killers kill if he were to be in such a hospital (Bardsley and Bell, 2005).

When the jury came back with its verdict after his trial, DeSalvo was found guilty on all counts. He was denied his requested psychiatric help and was sentenced to life imprisonment in a maximum security prison. DeSalvo’s defense attorney was outraged. He said:

> *"My goal was to see the Strangler wind up in a hospital, where doctors could try to find out what made him kill. Society is deprived of a study that might help deter other mass killers who lived among us, waiting for the trigger to go off inside them* (Bardsley and Bell, 2005)*."*

Recently, serious inquiries into the truth about the Boston Strangler have been conducted. Most notably, the case of Mary Sullivan was reopened. Investigators are using DNA evidence, as well as other evidence, to determine whether Albert DeSalvo really was the Boston Strangler. There are many questions as to the Strangler's true identity, and it could conceivably be true that he is still living in New England. A week before his death, DeSalvo asked to be moved to the infirmary under a special lockup for his protection. Just before he was killed in prison, Albert DeSalvo called the psychiatrist at the jail where he had been before his trial. He informed him that he had asked to be moved to the infirmary under a special lockup for his protection about a week prior. Dr. Robey believed that something was wrong, and stated that DeSalvo sounded afraid on the telephone. He claims that DeSalvo told him that he wanted to tell him who the real Strangler was. Dr. Robey agreed to meet with him in the morning. Unfortunately, DeSalvo was stabbed to death just hours after the phone call. He never got to meet with the psychiatrist (Bardsley and Bell, 2005).

With this in mind, a new investigation was started nearly 30 years after DeSalvo's death. The body of Mary Sullivan was exhumed to collect DNA evidence. Investigators were able to extract several items for examining, including a head hair from the pubic region of her corpse (Weubben, 2001). Fingerprinting of the DNA found in her pubic region and on her underwear would show that the DNA belonged to neither DeSalvo nor her. Another examination of his confession further showed that DeSalvo got the facts about the murder wrong. This and other evidence certainly seem to exonerate Albert DeSalvo and suggest that the real Boston Strangler is still at large (Borger, 2001).

The OJ Simpson Trial

Living rooms all over the United States, and perhaps even the world were filled with images of a white Ford Bronco moving slowly along the Los Angeles Freeway with a procession of police vehicles following behind it on the afternoon of June 17th, 1994 (see Figure 3). Inside was Orenthal James "OJ" Simpson, fleeing the authorities investigating him for the double-murder of his former wife Nicole Brown and her friend Ronald Goldman. The media coverage devoted to this pursuit served as fitting foreshadowing to his slow-paced and widely publicized murder trial.

Figure 3: Simpson's low-speed chase in his white Ford Bronco.

Five nights prior, Nicole Brown and Ronald Goldman were stabbed to death outside her Los Angeles condominium. The evidence at the crime scene was enough for police to make OJ Simpson a suspect in the investigation. Despite the fact that the crime demanded that no bail could be set, OJ's legal counsel was able to sway the Los Angeles Police Department to allow Mr. Simpson to turn himself in at 11am on June 17th. As the hour came and passed, police and thousands of reporters grew concerned as to the whereabouts of OJ Simpson. Police officials ordered an all-points-bulletin for OJ, and he was spotted nearly five hours later on the freeway. The lengthy and slow chase ended nearly two hours after Simpson was spotted and he was taken into police custody (see Figure 4) (Wikipedia, 2005).

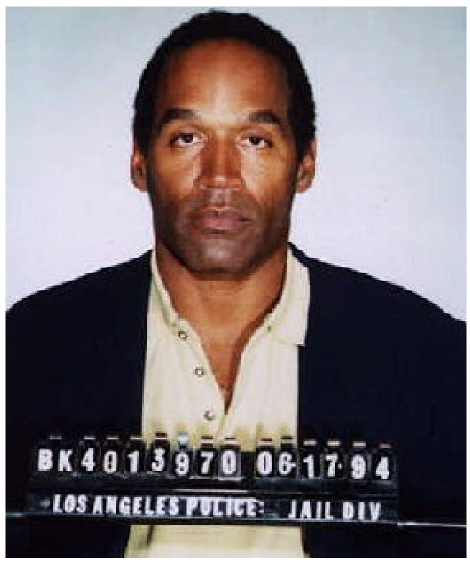

Figure 4: OJ Simpson's Police Mugshot (Linder, 1995).

There was multitude of incriminating evidence recovered for the criminal trial. Among other evidence, blood was found at the crime scene, in Simpson's Bronco, and at his home in the foyer and the master bedroom in a search of his estate. Furthermore, OJ had fresh cuts on his left hand on the day following the murder. These were thought to be sustained during a struggle with Mr. Goldman by the prosecution. Also there was a left glove found at the crime scene which matched a right glove found at the Simpson estate. The gloves were both black Aris Light gloves, size XL; they are of the same type and size of a pair of gloves purchased by Nicole Brown in 1990. Simpson was known to have worn Aris Light gloves from 1990 until June 1994, the same month in which the double-murder was committed. It was also well known that Simpson and Brown had a history of violence. Their abusive marriage had ended in 1992 in a divorce (Linder, 1995).

The blood collected near the bodies was so dried up that its DNA material was destroyed. It was impossible to match this blood with OJ's blood. Later, on July 2nd, fresh blood was found on Nicole Brown's back gate. This blood was not catalogued with the other evidence recorded on June 13th and 14th. This blood matched OJ's blood. The fingerprint of the DNA is common to only 0.5% of the population so it is very likely that the blood was indeed that of OJ Simpson. Because the blood was still fresh days later, when the other blood was far too dry for examination weeks earlier, it was believed that the blood was planted there so as to wrongfully incriminate Mr. Simpson. Because of this, a DNA fingerprint of this sample did not help convict OJ Simpson. If anything it served to damage the integrity of the evidence in the minds of the jury (Wikipedia, 2005).

Seeing the evidence against him, OJ Simpson went about to assemble a high-powered, and very expensive legal team for his defense. His "Dream Team", as it was dubbed by the media, was estimated to have cost $4 million (CNN, 1996). The team consisted of twelve attorneys and included such high-profile lawyers as F. Lee Bailey, Robert Shapiro, and Johnnie Cochran. It was a concern that with so much money, OJ might be able to get away with murder. The prosecution, however, was confident and felt they had a strong case against Mr. Simpson (Wikipedia, 2005).

During the trial, the issue of the matching gloves came to play a rather domineering role in the court. Mr. Simpson was asked by the prosecution at one point to try on the glove recovered from the crime scene. OJ tried to put the glove on, but it would not fit onto his hand over the latex glove he was wearing under it. This seemed to the defense to be a compelling testimony to the idea that Mr. Simpson was not guilty of the crime. One of OJ's defense attorneys, Johnnie Cochran, went so far as to incorporate it into a now famous rhyme which he imparted during his closing remarks. He declared to the jury: "If the glove doesn't fit, you must acquit (see Figure 5) (Wikipedia, 2005)."

Figure 5: OJ Simpson trying on the black glove
(© Lee Celano/WireImage.com)

The trial continued on, and finally at 10am October 3, 1995 the verdict was read. The jury had deliberated for three hours, and an estimated 100 million television viewers tuned in for the decision. The jury foreman announced the verdict: not guilty. This was shocking to the prosecution as they felt that they had presented a solid case. The verdict was highly controversial, as it seemed that his money had allowed OJ Simpson to get away with murder (Wikipedia, 2005).

The Role of Sensational DNA Cases in Society

These cases are just two of many highly sensational cases in which DNA fingerprinting has played a role in the outcome of a trial. These cases bring DNA technology into the public consciousness. People are made aware of the nature of DNA and of the different forensic applications when they hear about it or read about it during one of these high-profile cases. These cases help new technologies evolve and become more commonly-accepted as they make more people aware of their existence and of their usages. DNA fingerprinting, as the technologies before it, will continue to benefit from its exposure in the media. More and more people will hear about it in the news every day. Society will come to recognize this new technique as a benefit to the judicial system as they have watched it incriminate the guilty as well as exonerate the innocent time and again on the news or in the papers. As society recognizes the good that this technology can do, it will receive more attention and consequently more funding. This will enable scientists to further improve the methods and fine-tune the technology to better serve the public in the future. This cycle will continue and help to bring the legal system closer to the ideal of a just society.

CHAPTER-5: DNA DATABASES

What is a DNA Database?

It can become the ideal component to helping solve murders, rapes, and much more. The future of DNA databases in criminal investigations is both exciting and controversial. So what is it about a database that is so intriguing?

The Federal Bureau of Investigation (FBI) has developed the world's largest DNA database on a national scale that includes the DNA profiles of convicted sex offenders and those convicted of other violent crimes. Based on the guidelines and suggestions by the Technical Working Group on DNA Analysis Methods (TWGDAM), a group composed of Federal, state, and local forensic scientists, the FBI has created CODIS, or COombined DNA Index System (Adams, 2000). The DNA Identification Act of 1994 allowed the FBI to create a national database for law enforcement purposes; in 1998, the National portion of the DNA Index went online ("The FBI's Combined DNA Index System Program," 2000). The CODIS program is simply software—software that is capable of connecting forensic laboratories across the country to help solve crimes. CODIS allows DNA profiles to be shared electronically, making it possible to establish relationships between crimes in different cities, and capture criminals that live in other states. CODIS is comprised of three levels: the National DNA Index System (NDIS), State DNA Index System (SDIS), and Local DNA Index System (LDIS) ("The FBI's Combined DNA Index System Program," 2000). The three levels are linked by CODIS to aid in crime solving. The National DNA database is the most extensive and allows CODIS labs to be linked across the nation. Forensic laboratories that comply with

CODIS regulations set by the TWGDAM and the DNA Advisory Board that was created by the DNA Identification Act are granted Federal funding to access the DNA profiles stored within the CODIS program (Adams, 2000). The DNA evidence goes up the hierarchy, originating at the local level and going up through the state and national levels; see Figure 1 ("Mission Statement"). With over 100 laboratories and over 1,000,000 profiles in the convicted offender index as of January 2003, CODIS has provided a convenient list of convicted offenders at the investigators' fingertips ("DNA Forensics," 2004).

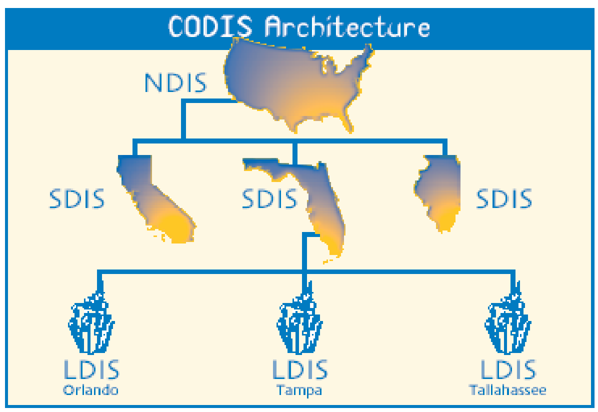

Figure 1: CODIS Hierarchy
From: The FBI's Combined DNA Index System Program Brochure, 2000

Evidence from a local crime scene is collected and analyzed; a DNA profile is created of the culprit. If there are no suspects in the case based on other evidence, investigators turn to CODIS. Using the convicted offender index, whether it is on the local, state, or national level, may provide a matching profile to the one found at the crime scene. If one is found, the identity of the now repeat offender can be obtained and the crime is solved. If there is no match in the convicted offender index, the profile will be searched for in the forensic or crime scene index, where profiles of biological evidence from various crime scenes are stored, even though a specific identity is not entered with the database entry. A match in these indexes establishes a link between crime scenes in different cities or states, and allows for different police departments to exchange information concerning these cases (Adams, 2000).

Why Use DNA Databases?

A DNA database filled with the profiles of convicted sex offenders and other violent criminals gives forensic laboratories the ability to analyze and potentially solve cases where there are no suspects or where there is no obvious connection to another crime in the local area. A serial or recidivist rapist or murderer can be identified through CODIS (Adams, 2002). But the success of CODIS is based on the number of profiles available in the database. In the first years of CODIS implementation, there have been many "hits" or matches of DNA profiles and cases have been solved (Figure 2). But there are still things that can be done to help increase the number of cases aided by a DNA database.

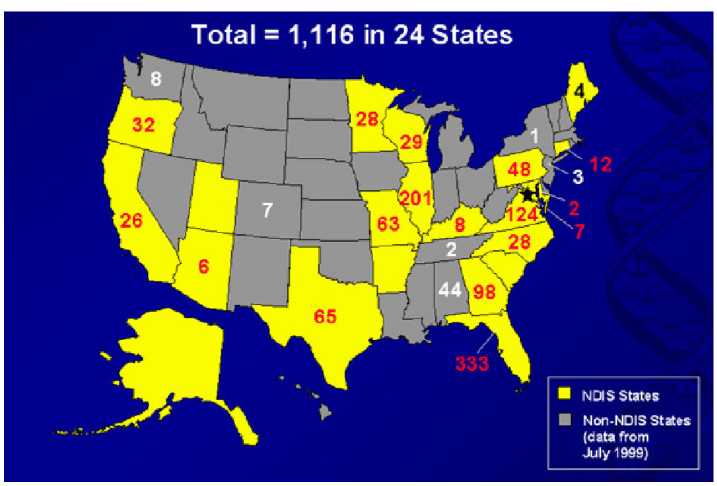

Figure 2: Number of Cases Solved Using CODIS and the National DNA Index System
From: Dr. Dwight E. Adams' Testimony, FBI, 2000

So what is keeping the FBI from having an enormous DNA database that includes every single offender, or even every single person, so that each crime can be instantaneous solved? The answer is privacy. The privacy issues regarding DNA sampling and database inclusions are discussed in the following sections.

What Goes Into a DNA Database Profile?

What has the ability to catch criminal offenders? The answer is junk DNA. A very unglamorous name for the part of DNA responsible for identifying rapists and murderers, but junk DNA is used by forensic investigators to get the job done. So what is junk? Over 95% of our DNA is so-called junk, garbage, or rather it is the non-coding part of our DNA (Suurkula, 2004). What the forensic laboratories are after is not the genes that we all share that make us be human, but the junk in between the genes (Dieter, 2001) (Figure-3). The genes responsible for coding proteins and creating our appearance are disregarded and only repeating sections of the DNA are analyzed and used to form a DNA fingerprint. As discussed in Chapter 1, junk DNA is composed of repeating sequences of base chemicals, otherwise known as tandem repeats. The short tandem repeats (STRs) make up the DNA fingerprint of a person because the numbers of repeats differ from one person to the next (Curran, 1997). It is the STR that varies in length, visibly in the assay, for each person and is used to make DNA matches ("Junk," 2004). The FBI analyzes 13 sites or loci on the DNA and uses the number of repeats at each site to identify a person, making the probability of two people having the same DNA very small, as discussed in Chapter 1.

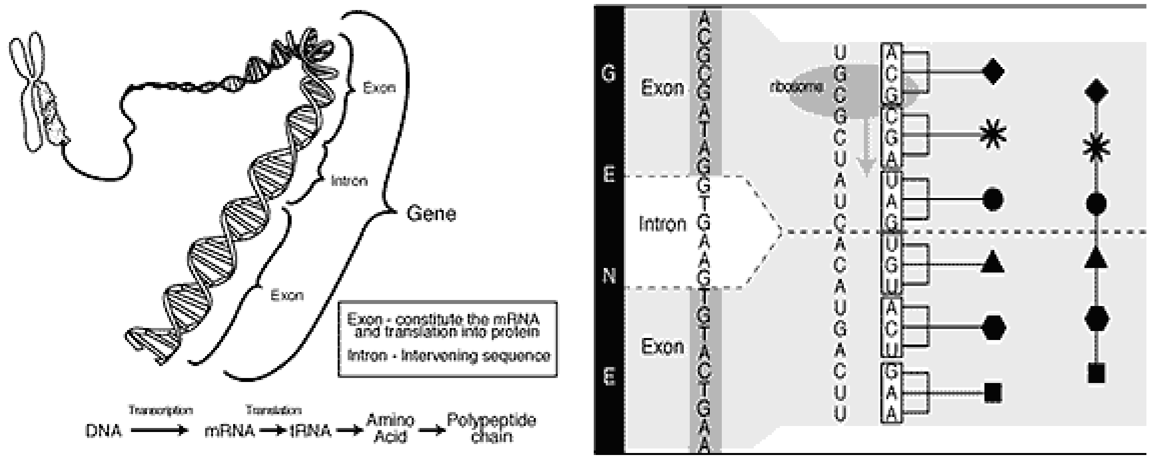

Figure 3: Genes are composed of exons and introns. Exons are templates for proteins, introns are filler, junk, nonsense—and critical for DNA fingerprinting.
From: Dieter, http://whyfiles.org/126dna_forensic/3.html, 2001

But doesn't DNA show everything about us? Can't it show what illnesses we are genetically predisposed to so that an innocent person providing DNA might be denied insurance coverage or a job? DNA research has led scientists to realize that DNA can provide many personal details about its owner; DNA can disclose a person's susceptibility to disease, legitimacy of birth, predispositions to certain behaviors, and sexual orientation ("DNA Forensics," 2004). But not all of your DNA sequence is entered into the database. The sample of DNA used in making a DNA profile, or fingerprint, of a person contains no genetic make-up information about that person (Curran, 1997). It's only a pattern that happens to be different for everyone, except identical twins; after all it is the part of DNA that scientists refer to as junk. As Tim Schellberg of Smith Alling Lane's Governmental Affairs Department puts it: "It means nothing other than saying you're not someone else" (Bersett, 2004).

So the NDIS is a database with junk DNA, not even the important part but the junk, and it can help in identifying criminals. If that's all it is, why isn't everyone's DNA in there already? The answer to that question is where the excitement of DNA data basing ends and the controversy begins.

DNA Database: An Invasion of Privacy?

Since a DNA sample before forensic analysis can theoretically disclose all your genetic secrets, being forced to provide the building blocks of your body seems wrong. A person does not go around giving his or her Social Security Number to anyone who asks; a person is careful about releasing this important form of identification. What kind of information would a blood sample reveal about you? Who will see this information? And the debate begins: the ability to catch murderers versus the capability of knowing everyone's genetic makeup. Who puts their DNA in now? Who should put their DNA into a database? What is the biggest fear? What should be done to make DNA databases the perfect law enforcement tool?

Who Is Currently Required to Provide DNA Samples?

Right now the standard procedure in all states requires a DNA sample from sex offenders and other violent criminals. These crimes are not accepted in our society as something favorable; on the contrary, it is always satisfactory to catch rapists and murderers and make sure they are locked up, away from society. The violent crime offenders are subjected to the harshest punishments, therefore an invasion of their privacy for a DNA sample is justified by the idea their right to privacy is reduced by society (Mayer-Schönberger, 2003). If a common thief and a serial murderer are being searched for, the murderer would receive more attention, more effort to insure a capture. It would be the highest priority to catch the murderer. Collecting a DNA sample from that murderer after his or her capture doesn't seem wrong, it seems necessary. After all, even non-convicted suspects in an arrest have to provide normal fingerprints to the arresting officers. In the event the murderer repeats a heinous crime, he or she can be quickly identified and recaptured. A benefit and a service to society are solid enough grounds to invade the offender's privacy and collect a DNA sample so that a profile can be created. But what of the common thief and his DNA?

"The states are learning quickly that, the larger the size of the database, the more crimes are solved" states Dr. Dwight E. Adams in his Congressional Testimony about the CODIS Program (2002). An example that Dr. Adams provides is that of Virginia. Virginia legislation has allowed DNA samples to be collected from sex offenders and from *all* other felons, creating an extensive database. Searching through the database filled with DNA samples of nonviolent offenders, a study showed that some rapists would not have been identified by solely looking at violent offenders; their profiles matched the ones on file from a burglary or a drug offense. The FBI is in favor of collecting DNA samples from all felons, and many states have included nonviolent offenses in their state databases. Table 1 shows what offenses each state includes in their database. States in bold print cover all felony offenses (Adams, 2002).

Many states are expanding their databases to include nonviolent offenders. In 2000, New York passed legislation that required 100,000 convicted violent criminals *and* nonviolent criminals to give DNA samples to be added to the state's database (Chebium, 2000). The bigger the databases the more likely a hit will happen. Prosecutors intent on preventing rapes and murders support databases and the increase in offenses subjected to DNA testing due to the databases' ability to provide fast protection for the public (Dieter, 2001). Massachusetts passed legislation in 2003 to collect DNA samples from any adult convicted of any felony (Massachusetts District Attorneys Association, 2004). With statistics from other states that have expanded their databases showing an increase in cases solved using the NDIS system, the inclusion of all felons in Massachusetts' database seems to be a favorable idea for law enforcement agencies. The more profiles the more hits.

FEDERAL & STATE DNA DATABASE LAWS QUALIFYING OFFENSES

	Sex Offenses	Offenses Against Children	Murder	Assault & Battery	Robbery	Kidnapping	Burglary	Attempts	Juveniles
Alabama	x	x	x	x	x	x	x	x	
Alaska	x	x	x	x	x	x	x	x	x
Arizona	x	x	x			x	x	x	x
Arkansas	x	x	x	x	x	x	x		x
California	x	x	x	x	x	x	x	x	x
Colorado	x	x	x	x	x	x	x	x	x
Connecticut	x	x				x			
Delaware	x	x						x	
Florida	x	x	x	x	x	x	x	x	x
Georgia	x	x	x	x	x	x	x	x	
Hawaii	x	x	x			x			
Idaho	x	x	x	x	x	x		x	x
Illinois	x	x	x		x	x	x	x	x
Indiana	x	x	x	x	x	x	x		
Iowa	x	x	x	x	x	x	x	x	
Kansas	x	x	x			x	x	x	x
Kentucky	x	x	x	x	x	x	x	x	x
Louisiana	x	x	x	x		x		x	x
Maine	x	x	x	x	x	x	x	x	
Maryland	x	x	x	x	x	x	x	x	
Massachusetts	x	x	x	x	x	x	x	x	

Michigan	x	x	x	x	x	x	x	x	x
Minnesota	x		x	x	x	x	x	x	x
Mississippi	x	x				x			
Missouri	x	x	x	x		x			
Montana	x	x	x	x	x	x	x	x	x
Nebraska	x	x	x			x		x	
Nevada	x	x	x	x	x	x	x	x	
New Hampshire	x								x
New Jersey	x	x	x	x		x		x	x
New Mexico	x	x	x	x	x	x	x	x	x
New York	x	x	x	x	x	x	x	x	
North Carolina	x		x	x	x	x			
North Dakota	x	x	x	x	x	x		x	
Ohio	x	x	x			x	x	x	x
Oklahoma	x	x	x	x	x	x	x		
Oregon	x	x	x	x	x	x	x	x	x
Pennsylvania	x	x	x					x	x
Rhode Island	x	x	x	x	x	x	x		
South Carolina	x	x	x	x	x	x	x	x	x
South Dakota	x	x	x	x	x	x	x	x	x
Tennessee	x	x	x	x	x	x	x	x	x
Texas	x	x	x	x	x	x	x	x	x
Utah	x	x	x	x	x	x	x	x	x
Vermont	x	x	x	x	x	x	x	x	x
Virginia	x	x	x	x	x	x	x	x	x
Washington	x	x	x	x	x	x	x	x	x
West Virginia	x	x	x	x	x	x	x	x	
Wisconsin	x	x	x	x	x	x	x	x	x
Wyoming	x	x	x	x	x	x	x	x	
Department of Defense	x	x	x	x	x	x	x	x	
District of Columbia	x	x	x	x	x	x	x	x	

Federal	x	x	x	x	x	x	x	x	
Puerto Rico	x	x	x	x	x	x		x	
Total	54	51	50	43	40	50	40	43	28

Table 1: Felony Offenses Included in State's Databases
From: From: Dr. Dwight E. Adams' Testimony, FBI, 2002

Who Should Provide Their DNA Samples?

Is there enough social benefit to capturing a burglar and then collecting and storing his or her DNA? When compared to a serial rapist, a thief does not seem to render as much alarm. But larceny is a felony, and DNA legislation has moved speedily down the list of crimes to include in state databases (Steinhardt, 2003). In addition, research shows that there is a strong correlation between property criminals and violent criminals: persons who commit a property crime indicate a strong tendency to commit a crime against a human (Mayer-Schönberger, 2003). Virginia has put rapists and murderers in jail because of DNA profiles gathered from drug offenders and burglars. Collecting DNA from a thief seems justified. But there is argument that it is not justified. Every time a profile is searched for and accessed in CODIS, that person's privacy is violated; the identity of that person is examined and connected to some crime (Mayer-Schönberger, 2003). With this argument, the murderer's profile can be accessed every time, but the thief's can only be accessed if the initial search of the convicted murderers' database is fruitless.

Whether it is a convicted rapist or burglar, these people have done harm against society and are paying for their crimes. Their DNA profile is stored in the event of a repeat of their crimes. Convicted felons should supply a sample of DNA to be added to the database. But what about those that were not convicted, rather they were merely arrested for a crime? Some states feel it is necessary to collect DNA samples from arrestees, like Louisiana and California (Steinhardt, 2003). These collections expand the database and allow a speeding ticket to catch a violent criminal; but is the database going to far when it contains innocent people?

There are cases where police have taken to the streets, asking people to cooperate with the police investigation by handing over their blood for DNA samples (Bersett, 2004). In fact, the Colin Pitchfork case in England, the world's first conviction for murder based on DNA, involved the citizens of a local town all submitting their DNA to the police. These people were targeted by either living in the area of the crime, or fitting a description of the suspect. The DNA "dragnet" in Baton Rouge, Louisiana produced over 1,000 DNA samples that gave police no suspect (Bersett, 2004). But the DNA dragnet did produce a lawsuit. The people who were forced to give a sample of DNA want it back or destroyed, since they have been proven innocent. Though people were offered the "choice" of giving their DNA, there was really was no choice. The American Civil Liberties Union (ACLU) do not see DNA dragnets as voluntary but rather as an invasion of privacy: "Being approached by a police officer and asked to give a 'voluntary' DNA sample could lead a reasonable person to believe that he has no choice but to consent to the request…such coercive behavior is a violation of the Fourth Amendment to the Bill of Rights, which protects an individual's privacy until evidence is produced and a warrant obtained that would compel an invasive search" (Bersett, 2004). The Fifth Amendment against self-incrimination is also violated when people's DNA samples are demanded by authorities. Does the violation of privacy justify the end result, a national all-inclusive DNA database used for law enforcement?

The United States has a track record of finding new functions for old practices. People are worried law enforcement is not the only purpose of a national DNA database. Social Security numbers have evolved to become a number that needs to be protected because it is the most common identifier for every person; this was not the plan for Social Security in the 1930s (Steinhardt, 2003). Now we are no longer dealing with numbers but human genes. The temptation to use all the collected DNA samples to conduct research is a genuine concern for people against the databases. A study of hereditary disorders, sexual orientation, and even a predisposition to crime can be carried out using our DNA. The XYY syndrome which targeted men who have an extra Y chromosome as more prone to violent and criminal behavior was a genetic stereotype that was used to discriminate against men in prisons (Annas, 2003). Studies have shown that the XYY syndrome is not completely responsible for criminal behavior or antisocial personality disorder (Steinhardt, 2003). And though the DNA of convicted felons is available in the NDIS, prisoners are humans too. They should not be used as test subjects in a genetics science project without their knowledge and consent (Annas, 2003). What measures are being taken to make sure that the DNA is only used for forensic purposes, not genetic research? How can people be sure that their intimate genetic makeup does not find its way to insurance companies and employers?

The knowledge that only junk DNA is used to create a DNA fingerprint of a person does not completely make these privacy issues obsolete. Scientists are recently discovering that the junk DNA may not be junk at all. Rats, mice, chickens, dogs, fish, and humans all have identical chunks of what is referred to as junk DNA; that means millions of years of evolution of each species did not alter the code (Kettlewell, 2004). If evolution left these pieces of genetic code alone, scientists are trying to find out exactly why this would happen. These similar regions of junk DNA are usually clustered around genes that are important to embryonic development, making scientists think they have an effect on the way we develop (Kettlewell, 2004). Harvard researchers have found a new gene in yeast, whose sole function is not producing yeast like a normal functioning gene ("Junk DNA Yields New Kind of Gene," 2004). The new gene's function is simply to be turned on, so that the gene next to it can perform its job. If the junk DNA of yeast can produce a new gene, what does the human "junk" DNA have in store for us? The idea that junk DNA may reveal our genetic secrets makes people less willing to give their DNA. Many states have DNA laws that do not include any directions as to what to do with the samples and accompanying record once a person is proven innocent ("DNA Forensics," 2004). When DNA dragnets found no suspects, the DNA profiles for those innocent individuals remained on record.

Those innocent citizens' DNA are now included in a database with weak protection laws guarding against the misuse of the DNA information. If the insurance company obtains the knowledge that an individual is susceptible to a disease, it would result in a denial of coverage for that person so that the insurance company can avoid the future costs of care. Massachusetts DNA laws are an example of inadequate security for very sensitive information. Written consent is required for predictive genetic testing and also if the person wishes to disclose this information to a doctor (Annas, 2003). Insurers and employers have only limited uses for the genetic information. But the law puts no limitations concerning biotech companies and researchers; most of the activities of these companies are not regulated by the federal government, the same federal government that regulates research with human subjects (Annas, 2003). Not a comforting thought: the identifiable information about a person can be obtained by researchers and studied. Massachusetts law also states that DNA results can be used for “humanitarian purposes” without defining the phrase (Chebium, 2000). New York law states DNA samples can be used for law enforcement purpose only; Massachusetts law has a “loophole you can drive a truck through” (Chebium, 2000). The laws protecting DNA databases need to be standardized across the nation.

Conclusion and Recommendations

The most general requirements recommended by the authors of this IQP are a clarification of the types of genetic information that can be obtained from a person’s DNA, protections against genetic discrimination by employers and insurance companies, and the requirement that samples should immediately be destroyed after forensic analysis (Chebium, 2000). A person’s DNA should be considered the property of that individual and genetic privacy laws should reflect that. An individual who is not a convicted felon should have his or her genetic rights recognized by:

- Having the right to determine if and when their DNA is collected, stored and analyzed
- Having the right to access their own DNA samples and genetic information
- Having the right to determine who has access to this information
- Having the right to know all the things involved in DNA collection, storage, analysis, and disclosure of their genetic information

(Annas, 2003). The destruction of a DNA sample is also a major privacy concern. Once the sample is analyzed, the non-junk part of the DNA should not be kept as a backup and a temptation to be used in genetic research. An argument in favor of keeping DNA samples is that technology will advance and there might be a new method of identifying criminals with DNA. Those in favor of sample destruction see no reason why a new sample can not be drawn from the suspect and retested with the new method (Mayer-Schönberger, 2003), and we agree with this conservative stance. The purpose of a national database is identification, so the samples, once analyzed and a DNA fingerprint developed, should be destroyed. The promise of technological advances is not strong enough grounds to justify keeping the samples; technical advances may or may not happen (Mayer-Schönberger, 2003).

There is no guarantee that DNA databases will be used for other things besides law enforcement. The possibility of having every person's DNA profile on record is enticing: more crimes would be solved, new gene research could be performed, and what makes us unique studied. But potential discrimination by insurance companies, employers, even future spouses who do not like the way your genes look is an unwanted side effect of DNA databases.

The debate about privacy still rages as state laws change to include new excuses to gather more DNA samples. Having a cotton swab inside your mouth does not seem like a massive invasion of privacy; it is what might happen to the DNA on that cotton swab in years to come that may make you rethink giving it.

CHAPTER-6: DNA CONCLUSIONS

While DNA fingerprinting may still be a new and controversial method for dealing with all applications from forensics to archeology, DNA fingerprinting is something that will only get bigger and more universally accepted with time. Because one can not *alter* one's DNA sequence after leaving it at a crime scene, and because it is hard to prevent *leaving* DNA at a crime scene, DNA analysis is arguably the greatest forensic tool in the history of forensic science.

Out of the three main kinds of DNA fingerprints, RFLP, VNTR, and STR, STR is the most common. The first two take a lot of DNA which is usually very hard to find at a forensic scene, and often the DNA fragments being analyzed are too long to amplify via polymerase chain reaction (PCR). STR on the other hand uses short sections of DNA which are ideal for running a PCR, thus the forensic DNA can be amplified. The volume is increased exponentially making it easier to run tests on small samples of DNA. Also, STR analysis also does not require hybridization to a DNA probe, which is a time consuming step.

Forensics took a large step when advancing to using DNA to solve crimes which, in the past, have been unsolvable. Before DNA fingerprints, the evidence that was collected often did not eliminate enough people, and it was often possible that two or three suspects matched the evidence found at the scene. This evidence includes hair, standard fingerprints, and blood types. DNA is much more individualized, and it is extremely rare that the DNA will match more than one person on this planet.

One of the biggest advances allowing DNA evidence to be accepted in the courtroom was a standardization of DNA collection and it analysis. Previously the biggest problems were contamination and degradation. However forensic science has advanced to where these can be controlled. When the first DNA fingerprints were produced it was not as well studied how to properly gather, store, and test DNA from crime scenes. Since its first introduction these steps have been extremely refined and more universally accepted. Containers for the collection of DNA have even been created to retain as much usable DNA as possible. Brown paper bags for clothes and small envelopes are used so that moist DNA does not deteriorate that much. Vials for storing blood include an anticoagulant to prevent collected blood from going bad. Larger plastic containers are used to store tissue samples so that they don't dry out but need to be processed very rapidly after collection so as to not further deteriorate the sample.

Storage of DNA samples has also been perfected to ensure no further degradation of the DNA. DNA samples must be stored in extremely cold freezers, sometimes as cold as -20ºC. Blood, for instance, must be turned into blood stains so that during the defrosting phase the blood is not breaking down. After the DNA has been completely extracted from the samples and multiplied by a PCR machine, it must be stored in airtight vials in a -70ºC freezer. This is much cooler than a non-extracted DNA sample.

While DNA fingerprints can be 99.9% accurate in all cases where the analysis is performed properly, the DNA evidence must be allowed into court for it to have any bearing. For many years courts have been struggling to determine what kinds of evidence can be admitted. One popular trend setting case for the inclusion of technical evidence was *Frye v. United States*. In this trial, Frye was given a systolic blood pressure test that indicated he was "telling the truth". Back in 1923 the lie-detector was new, and it was not supported by experts in the fields of psychology, so the judge refused to allow it as evidence at trial. The Frye standard was created which states that any evidence included that comes from a technical nature, must be widely accepted by the experts in the field. But not all states adopted this standard due to the complications in determining exactly what “general acceptance” is.

Another case which has had a huge impact on DNA usage in courtrooms today was back in 1987 with *People v. Castro*. Castro was apprehended during a homicide investigation because he had a blood stain on his watch. This blood was taken to a laboratory to be tested against the victims and it was determined that the bloodstain was that of the victim’s. The trial eventually resulted in the most intensive review of DNA evidence theory performed at that time, with the determination that the procedure was not well performed in this specific instance, so it was not admitted. Thus the Castro case altered the Frye standard into a 3 pronged system; is the process generally accepted in its field, can reliable results be retrieved through a consistent procedure, and did the lab follow the exact specifications of the procedure when processing this specific case? Various versions of the Castro standard are still in practice today.

Another landmark case involved the usage of DNA for the prosecution of a suspect based only on DNA evidence rather than name or physical description. A warrant was filed when a series of women were attacked, thus stopping the clock on the statute of limitations for rape. Luckily, four years later a man was arrested and his DNA filed and it matched a hit for the outstanding warrant. If the original DNA warrant didn’t exist, this person would have gotten away with committing those crimes against several women.

There are countless trials in which DNA evidence was used so there is no real reason to repeat the outcomes of every one of them here. Two cases that might be more “real life” include the OJ Simpson case, as well as the Boston Strangler. DNA was very helpful in those cases and continues to be in most murderers and rapists trials.

The largest and most used criminal DNA database in the world is known as CODIS, COmbined DNA Index System. CODIS was set up as an electronic library of sex offender’s, and felons’, DNA fingerprints. The intent was to store this information so that if or when any one of these criminals gets out, if they break the law again it will be much easier to place them at the crime scene and then prosecute them as necessary. Unfortunately, there is much more to DNA than its forensic information.

DNA tells us everything, it can tell us what color hair we will have, it can tell us if we are genetically predisposed to get cancer, it can sometimes even predict violent behaviors, as well as mental disorders. This is actually the problem with using DNA to produce fingerprints. Once our technology reaches a point in genetic typing, we will be able to say whether or not someone is predisposed to get cancer when they get older, or some other disease. The question then lies, who can access this DNA information? This information could be used to discriminate against people who are genetically undesirable. Insurance companies can refuse to give you a plan because they don’t want to have to pay for treatment for a disease you will get in the future.

The authors of this IQP agree with the current legislation of the state of Massachusetts that requires all adults (not juveniles) convicted (not arrested) of crimes to provide a DNA sample. And we strongly support legislation requiring the original DNA sample to be destroyed immediately after obtaining the forensic information, thus preventing any non-forensic information from being obtained or stored. Although we agree that requiring all citizens of a country to provide DNA samples would likely increase the number of solved crimes, privacy rights would be violated. Adults convicted of a crime give up some privacy rights, and require DNA sampling. We also agree that legislation should strongly restrict who has access to the forensic information in the database.

Not now, but possibly in the future laws will be in place governing exactly who can access your DNA and determine how it is to be stored if at all. Once that happens, DNA fingerprints will become the next form of the Social Security number.

BIBLIOGRAPHY

Adams, Dwight E. (2000) "Forensic DNA Analysis" Congressional Statement, Federal Bureau of Investigation, U.S. Department of Justice. http://www.fbi.gov/congress/congress00/dadams.htm

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

Annas, George (2003) "Genetic Privacy." http://www.ksg.harvard.edu/dnabook/

Bardsley, Marilyn and Bell, Rachel S. (2005) "The Boston Strangler". Court TV. http://www.crimelibrary.com/boston/bostonmain.htm

Bersett, Kevin (2004) "Victims Challenge Police Use of Controversial 'DNA Dragnets'" The New Standard. http://newstandardnews.net/content/?action=show_item&itemid=1044

Betsch, David (2004) "DNA Fingerprinting in Human Health and Society." http://www.extension.iastate.edu/Publications/NCR550.pdf

Biotechnology Industry Organization (2003) "DNA Fingerprinting: Other Uses." http://www.bio.org/speeches/pubs/er/otheruses.asp

Borger, Julian (2001) "DNA Tests Clear Man Convicted as Boston Strangler" http://www.buzzle.com/editorials/12-7-2001-8511.asp

Butler, John M. and Reeder, Dennis J. (2004) "A Brief Introduction to STR's." http://www.cstl.nist.gov/biotech/strbase/intro.htm

Chebium, Raju (2000) "State DNA Laws Help Fight Crime, But Critics Cite Privacy Concerns" CNN.com. http://archives.cnn.com/2000/LAW/10/24/states.dna.cr/index.html

Christianson, Bryan (2000) "Molecular Archaeology" http://www.mnsu.edu/emuseum/archaeology/archaeology/moleculararchaeology.html

CNN (1996) "OJ Simpson Main Page" http://www.cnn.com/US/OJ/

"Crime Scene Investigation: A Guide for Law Enforcement" (2000) U.S. Department of Justice. http://www.ncjrs.org/pdffiles1/nij/178280.pdf

Curran, Thomas (1997) "Forensic DNA Analysis: Technology and Application" Science and Technology Division. http://www.parl.gc.ca/information/library/PRBpubs/bp443-e.htm#METHODS%20OF%20FORENSIC-DNA%20PROFILING

Delson, Gary (2001) "Cracking An Unsolved Rape Case Makes History". Sacramento Bee. http://www.aliciapatterson.org/APF2001/Delsohn/Delsohn.html

Dieter, Richard (2001) "Short, Ironic History" Crime Science Investigation. http://whyfiles.org/126dna_forensics/2.html

--- (2001) "Fingered by DNA" Crime Scene Investigation. http://whyfiles.org/126dna_forensics/3.html

--- (2001) "Junk Reading" Crime Scene Investigation. http://whyfiles.org/126dna_forensics/4.html

"DNA Evidence Collection at Crime Scene" Criminalistics Laboratory, Iowa Department of Public Safety. http://www.state.ia.us/government/dps/dci/lab/dna/DNA%20Evidence%20Collection%20At%20Crime%20Scenes.pdf

"DNA Forensics" (2004) Human Genome Project Information. http://www.ornl.gov/sci/techresources/Human_Genome/elsi/forensics.shtml

"Evidence Packaging" (1998) Evidence Collection and Protection, Inc. http://www.crime-scene.com/catalog/packaging.shtml

Fiatal, Robert A. (1989) "DNA Testing and the Frye Standard". http://www.totse.com/en/law/justice_for_all/dnatest.html

"Frye v. The United States". Frye. (1923) http://www.law.harvard.edu/publications/evidenceiii/cases/frye.htm

Genelex (2003) http://www.genelex.com

Hallick (2000) "The Biology Project" http://www.biology.arizona.edu/human_bio/activities/blackett2/overview.html

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

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

Hill, Walter (2004) “RFLP Definition” http://vm.cfsan.fda.gov/~frf/rflp.html

Human Genome Project (2004) “SNP Basics” http://www.ornl.gov/sci/techresources/Human_Genome/faq/snps.shtml

Huskey, Robert (1999) “DNA Fingerprinting using VNTR's” http://www.people.virginia.edu/~rjh9u/vntr1.html

“Junk” (2004) DNA Matching. http://library.thinkquest.org/04oct/00206/text_pti_dna_matching.htm#pti_junk

Kettlewell, Julianna (2004) “‘Junk’ Throws Up Precious Secret” BBC News Online Science. http://news.bbc.co.uk/2/hi/science/nature/3703935.stm

Khalsa, Guruatma (2004) “Molecular Kitchen” http://lsvl.la.asu.edu/resources/mamajis/southern/southern.html

Kramer, Robert E (2002) “DNA Evidence Collection Principles” Iowa Division, International Association for Identification. http://www.iowaiai.org/DNA.htm

Landau, Misia (2004) “Junk DNA Yields New Kind of Gene” Focus, Harvard Medical School. http://focus.hms.harvard/edu/2004/June4_2004/genetics.html

Linder, Douglas O. (1995) “Famous American Trials: The O. J. Simpson Trial” http://www.law.umkc.edu/faculty/projects/ftrials/Simpson/simpson.htm

Mayer-Schönberger, Viktor (2003) “Strands of Privacy: DNA Databases and Informational Privacy and the OECD Guidelines.” http://www.ksg.harvard.edu/dnabook/

Meeker-O’Connell, Ann (2004) “How DNA Evidence Works” HowStuffWorks. http://people.howstuffworks.com/dna-evidence.htm

“Mission Statement” CODIS Federal Bureau of Investigation. http://www.fbi.gov/hq/lab/codis/program.htm

Patton, Stephen M. (1990) “DNA Fingerprinting: The Castro Case”. Harvard Journal of Law and Technology (Volume 3, Spring Issue 1990). http://jolt.law.harvard.edu/articles/pdf/v03/03HarvJLTech223.pdf

Schiro, George (2001) “Collection and Preservation of Blood Evidence from Crime Scenes.” http://www.crime-scene-investigator.net/blood.html

Schumm, James W (1996) "New Approaches to DNA Fingerprint Analysis." *Notes Magazine, No 58.* http://www.promega.com/pnotes/58/5189c/5189c_core.pdf

Spear, Theresa F. (2004) "Sample Handling Considerations for Biological Evidence and DNA Extracts" California Criminalistics Institute . http://www.cci.ca.gov/Reference/biosmpl.pdf

"Standards for Forensic Testing DNA Labs" CODIS Federal Bureau of Investingation. http://www.fbi.gov/hq/lab/codis/forensic.htm

Steinhardt, Barry (2003) "ACLU Presentation on Privacy and Forensic DNA Data Banks" http://www.ksg.harvard.edu/dnabook/

Suurkula, Jaan M.D. (2004) "Junk DNA" http://www.psrast.org/junkdna.htm

"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

"The Future of Forensic DNA Testing" (2000) National Institute of Justice, U.S. Department of Justice. http://www.ncjrs.org/pdffiles1/nij/183697.pdf?linksPage=22

"What Every Law Enforcement Officer Should Know About DNA Evidence" (1999) National Institute of Justice. http://www.ncjrs.org/nij/DNAbro/intro.html

Wikipedia (2004) "Boston Strangler" http://en.wikipedia.org/wiki/Albert_DeSalvo

--- (2005) "Genetic Fingerprinting". http://en.wikipedia.org/wiki/Genetic_fingerprinting

--- (2005) "O.J. Simpson" http://en.wikipedia.org/wiki/O._J._Simpson

Wuebben, Mike (2001) "The Boston Strangler" http://www.cbsnews.com/stories/2001/02/14/48hours/main272108.shtml