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DNA FINGERPRINTING AND SOCIETY

An Interactive Qualifying Project Report

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By:

Lincoln Bates

Marisa Santos

Kayla Sousa

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APPROVED:

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

ABSTRACT

The purpose of this Interactive Qualifying Project (IQP) was to explore the emerging technology of DNA Fingerprinting and its impact on society, especially the judicial system and the ethics of DNA databases. Since the mid 1980's when DNA evidence first appeared in courtrooms, society has been skeptical of this new way to identify criminals, but following key landmark courtcases, and the creation of standard procedures for collecting, storing, and analyzing DNA evidence, this technology has slowly gained acceptance. Different procedures for DNA fingerprinting are described, as well as their uses and forensic applications. Various court cases involving the use of DNA forensics were studied. Lastly, the ethical concerns our society expresses toward DNA databases and genetic privacy were analyzed.

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PROJECT OBJECTIVES

The purpose of this Interactive Qualifying Project (IQP) was to investigate the science behind DNA fingerprinting technology and to document its social impacts. Information contained in the report includes how DNA is used to create DNA fingerprints, as well as an explanation of what DNA is. The importance of avoiding contamination and DNA degradation, and documenting chain of custody when collecting samples was shown. Also examined was a series of landmark court cases defining various criteria for allowing DNA evidence to enter courtrooms. Finally, the different views our society holds regarding DNA databases and genetic privacy were analyzed. This discussion is intended to help the general public understand this complex technology, and derive their own conclusions about who should contribute DNA to databases.

CHAPTER 1: DNA FINGERPRINTING, DESCRIPTION AND TYPES

DNA fingerprinting is a “DNA-based identification system that relies on genetic differences among individuals or organisms” (Biotechnology Industry Organization, 2003). DNA fingerprinting has many uses, including paternity disputes, molecular archeology, and forensics. At a crime scene, DNA can be found in hair, seminal fluid, saliva, skin, and blood. Before fingerprinting technology, blood samples were drawn, and the crude ABO blood grouping system was used to roughly determine to which major bloodtype group an individual belonged. Currently, it is not even necessary to draw a person’s blood for analysis, a simple, less invasive procedure, called a cheek swab, is performed to collect a few cells from the inside of the cheek (Collins, Richard, 2002). In this chapter we will simplify DNA structure for the average person, discuss the main fingerprinting types, and give examples of fingerprinting applications. Knowledge of this technology is important to understand its impact on society, discussed in later chapters.

DNA STRUCTURE

Deoxyribonucleic acid, commonly referred to as DNA, represents the genetic material of every organism (Briton and Lieberman, 1994). Chromosomes, contained in the cell nucleus, contain genes, the functional subunit of heredity information passed from parent to offspring (Figure 1) (The National Health Museum, 2008). Chromosomes contain DNA as well as protein. Humans have 23 pairs of chromosomes, half from each parent, for an overall total of 46 chromosomes (Rohloff, 2000).

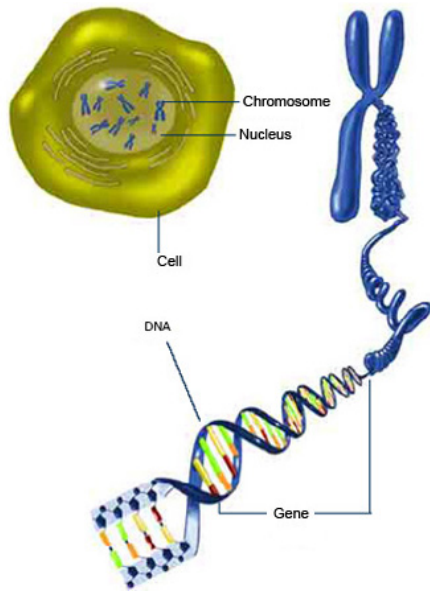


Figure 1: Diagram of DNA Coiled Into Chromosomes. Upper left shows a typical eukaryotic cell with chromosomes in the nucleus. A chromosome is magnified in the upper right, and unwound to show its DNA (lower center) (National Institute of General Medical Sciences, 2006).

In the shape of a double helix (Figure-2), DNA is comprised of nucleotide subunits consisting of a deoxyribose (sugar) phosphate backbone and four nitrogenous bases (The National Health Museum, 2008). To create a coding sequence, the four bases adenine (A), thymine (T), guanine (G), and cytosine (C), also known as nucleotides, covalently bond to one another (shown as rungs of the ladder in the figure). However, not all bases can bond: adenine will only pair with thymine, while guanine pairs with cytosine. These base pair bonds connect the two sugar phosphate backbones similar to the shape of a ladder (Figure 2) (U.S. National Library of Medicine, 2008).

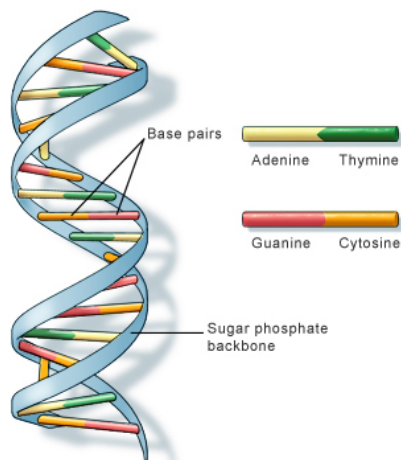


Figure 2: Diagram of the DNA Double Helix. The overall structure is composed of individual base pairs (rungs on the ladder) connecting to a sugar phosphate backbone (blue). A larger view of the base pairs (right) shows the A-T and G-C bonds (U.S. National Library of Medicine, 2008).

The human genome, containing 3 billion DNA bases, was recently sequenced, and took years to accomplish. But in order to identify an individual based on his or her genetic make up, a scientist need not analyze an entire DNA molecule, but rather specific sites (or loci) on the DNA molecule. A locus is a specific position on a chromosome such as a genetic marker or the start of a gene (Human Genome Project Information, 2008). Currently 13 core loci have been approved for standard forensic analysis in the United States. The data can be entered into CODIS, the Combined DNA Index System, a DNA profile database monitored by the FBI (Federal Bureau of Investigation, U.S. Department of Justice, 2008).

Only 0.10% of a DNA molecule distinguishes an individual's DNA fingerprint from one another, with the exception of identical twins who share the same DNA (Human Genome Project Information, 2008; Rudin, 1995). Over 95% of DNA's function remains unknown to scientists. The unknown sections of DNA are non-coding, polymorphic regions of DNA called introns, or "junk DNA" (Bergman, 2001; Suurkula, 1997). These non-coding sequences are the regions of the genome where forensic scientists can see differences among individuals, and therefore they provide a possible identification of a criminal suspect.

Non-coding DNA containing many repeating base pairs of different lengths are analyzed during DNA profiling. The length of a tandem repeat (the repeated end-to-end duplication of a core DNA sequence at a defined locus) varies from person to person. Specific loci contain a certain number of repeats which are classified into groups, depending on the tandem repeat length. Variable number tandem repeats (VNTRs) have repeats with 9-80 base pairs, while short tandem repeats (STRs) only contain 2-5 base pair repeats (Butler and Reeder, 2007).

FINGERPRINT TECHNOLOGY TYPES

Scientists have developed two main methods to examine differences in DNA. The first is Restriction Fragment Length Polymorphism (RFLP) which is usually used to analyze relatively long VNTRs, and the second is Polymerase Chain Reaction (PCR) which is usually used to analyze relatively short STRs. Each method has advantages and disadvantages. Many factors, including the amount of DNA available, urgency, contamination, and cost, contribute to determining which method will be used (Biotechnology Industry Organization, 2003).

RFLP Type Fingerprints

The first method of DNA fingerprinting is called Restriction Fragment Length Polymorphism (RFLP). RFLP fingerprinting was first used in 1987 in Scotland, and since then it has been used in thousands of court cases (Collins, 2002). RFLP fingerprinting analyzes the lengths of specific DNA bands excised from the main DNA molecule by cutting with restriction enzymes. The band lengths vary depending on the number of repeating sequences. These repetitions, known as Variable Number Tandem Repeats (VNTRs), can repeat from one to thirty times (Meeker-O'Connell, 2004).

RFLP fingerprinting, compared to other techniques, has limitations. The main limitation is the initial amount of DNA needed for analysis (Table 1) (Micro 7: DNA Fingerprinting, 2004). This procedure does not amplify the DNA, so if there is not enough DNA present, RFLP fingerprinting cannot be performed. Additionally, RFLP fingerprinting is a slow process. Analysis typically requires about 3-4 weeks of laboratory work under the best circumstances (Collins, 2002).

Sample Size for RFLP Fingerprinting	
Blood	15 μ l
Semen	5 μ l
Skin	5 mg

Table 1: The Amount of DNA Necessary for RFLP Type Fingerprints.
(Micro 7: DNA Fingerprinting, 2004).

To perform an RFLP fingerprint, one must have an unidentified DNA sample to compare to a sample from a known source (Figure 3). The DNA is isolated from a crime scene sample using organic extractions, then it is cut at specific sequences using a restriction enzyme. The DNA fragments are then separated by size using gel electrophoresis. Once separated by size, the DNA bands are denatured to single strands to allow hybridization to a probe. The DNA fragments in the gel are then blotted to a thin white membrane (based on the Southern blot procedure), and the membrane is soaked in a solution containing a radioactive single-strand DNA probe complementary to the VNTR sequence to be analyzed. Any non-hybridized free probe is removed by washing the membrane, then the membrane is exposed to film to locate the bands that hybridized to the probe. The data looks like a bar code (Figure-3), and aligning bands means identical samples (Micro 7: DNA Fingerprinting, 2004).



Figure 3: Example of an RFLP-Type DNA Fingerprint. A DNA gel plate compares an unidentified (crime scene) sample (upper) to four known samples (suspects). The crime scene sample matches suspect-3 (Trendy Sciene, 2007).

PCR Type DNA Testing

The second main method of DNA fingerprinting is Polymerase Chain Reaction (PCR). PCR fingerprinting is a newer technique that is often used as a preliminary step in the most commonly used STR type of forensic analysis (Meeker-O'Connell, 2004). PCR is a “technique used to amplify the number of copies of a specific region of DNA, in order to produce enough DNA to be adequately tested” (Brown, 2006). The main advantage of PCR is the ability to analyze small amounts of DNA by amplifying it (Figure 4). However, due to its sensitivity, PCR fingerprinting is prone to possible contamination.

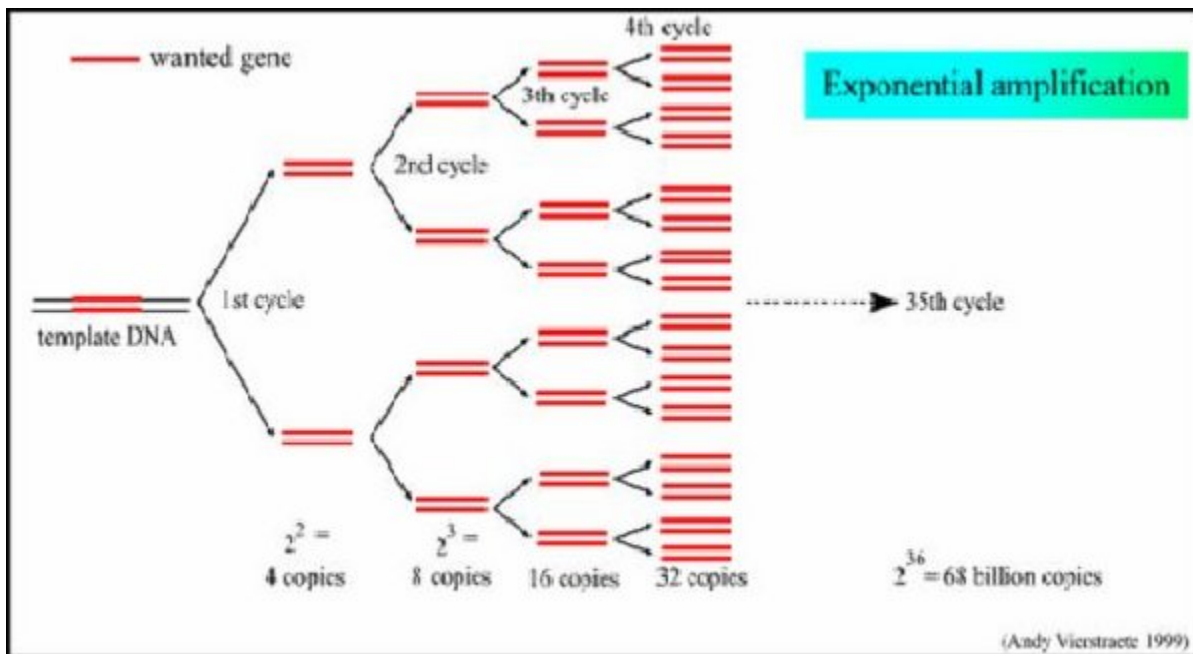


Figure 4: Diagram of the Amplification of DNA Using PCR. The desired locus (shown in red) is specifically amplified from a small amount of DNA sample by flanking it with primers specific for that locus. One PCR cycle produces two complete DNA molecules. The process proceeds exponentially (iGem 07, 2007).

The process of creating a PCR fingerprint consists of three major steps (Figure 5). These steps repeat about thirty or forty cycles. The first step is denaturation at 94°C. During this step

double-stranded DNA unfolds to single-strand DNA and all reactions stop. Next comes annealing of the template DNA with primer sequences that flank the locus to be analyzed. Annealing is performed at 54°C and forms double stranded polynucleotides. The last step is DNA extension which occurs at 72°C, which is the best working temperature for the heat-stable Taq polymerase added to the reaction (Vierstnete, 1999).

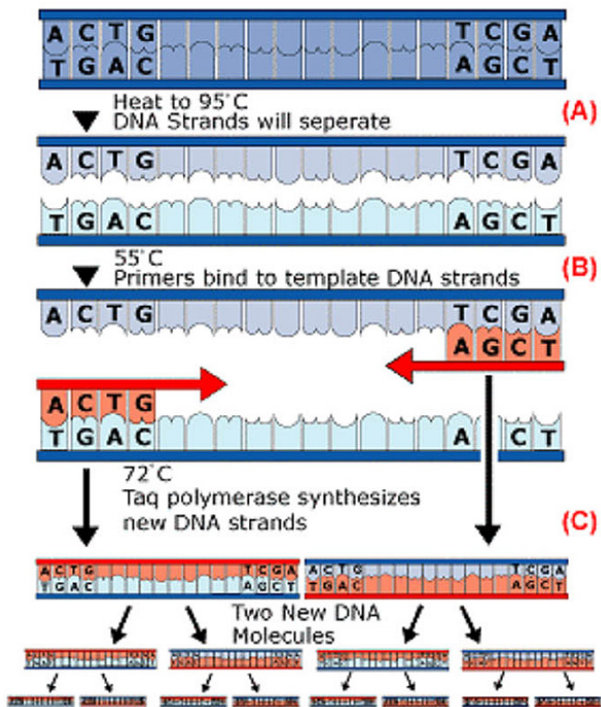


Figure 5: Diagram of the Three Main Steps of PCR. (U.S. Department of Commerce, 2005).

PCR only works to amplify relatively short DNA fragments, thus PCR is usually applied to STRs, not to VNTRs. VNTRs are too long to amplify efficiently by the PCR process. “STR analysis examines how often base pairs repeat in specific [relatively short] locus on a DNA strand” (Meeker-O’Connell, 2004). Repetitions can be of two, three, four or five base pairs. The more base pairs repeated, the more likely they are to be accurate. The FBI’s CODIS database currently uses STR analysis examining 13 loci. The odds of two people having matching 13-loci STR profiles are approximately one in a billion (Meeker-O’Connell, 2004).

FINGERPRINTING APPLICATIONS

The most significant new tool in the history of forensic science, DNA fingerprinting, has many applications including Paternity Testing, Criminal Forensics, and Molecular Archeology. DNA fingerprinting does, however, have challenges. The main challenge is data protection. Along with data protection comes the concern of an individual's right to privacy.

Paternity Testing

Paternity determination is currently one of the most popular uses of DNA fingerprinting. Fingerprints of the mother, child, and possible father(s) are compared using RFLP analysis (Figure 6). The DNA matches between the mother and child are subtracted from the pattern, and the remaining DNA is compared to the DNA of the possible father (DNA Fingerprinting: Other Uses, 2008). DNA tests can be up to 99.99% accurate, which is why they are popularly used in paternity disputes.

There are many reasons why paternity tests are conducted. Results of paternity tests are often used in legal matters involving child support. For example, in a custody dispute in which the alleged father refuses to pay child support, the DNA results are used to verify that he is indeed the father. DNA testing is also used in child custody disputes and is often a deciding factor of who will have legal access to the child. Insurance companies also require paternity tests before a child can be added on to a father's insurance policy. This is most common when the mother and father of the child are not married (Paternity Testing, 2008). More recently, paternity testing has been used in Immigration cases to verify relatedness for individuals seeking to enter the country.

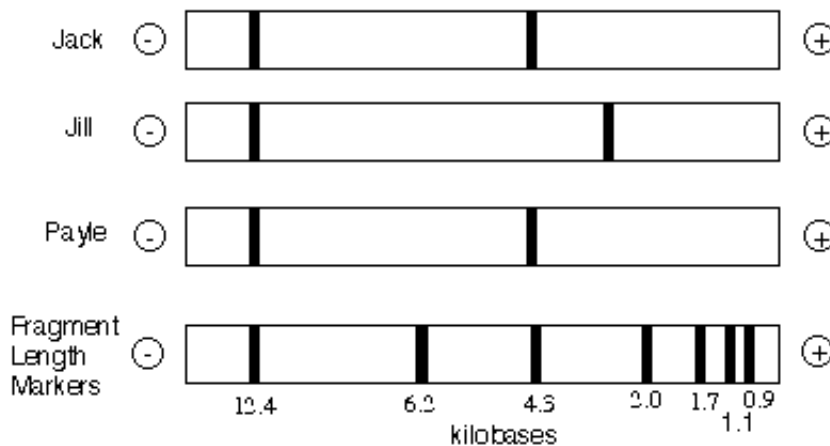


Figure 6: The Results of a DNA Paternity Test. Jack and Payle share a band at approximately 4.3 kilobases. This shows it is possible that Jack is Payle's father (Davidson College, 2006).

DNA Forensics

The use of DNA analysis in criminal cases is perhaps the most significant role of DNA fingerprinting. DNA samples at a crime scene including hair, skin and bodily fluids can be analyzed and compared with samples obtained from suspected perpetrators (Biotechnology Industry Organization, 2003). Today DNA fingerprinting is widely accepted, and many states have passed laws requiring individuals convicted of violent crimes to supply samples of their DNA to be placed into databases. The largest DNA database in the world is the FBI's Combined DNA Index System (CODIS). As well as helping convict guilty suspects, DNA fingerprinting has also helped prove individuals innocent for crimes they were convicted of prior to DNA fingerprinting technology. In addition, DNA fingerprinting is used to identify unknown individuals, including fallen soldiers and even the victims of the September 11, 2001 attacks on the United States (Biotechnology Industry Organization, 2003).

Molecular Archaeology

Molecular archaeology has been studied using DNA fingerprinting as well. Using DNA fingerprinting, scientists are able to study the evolution of human populations. In order to trace

migrations, scientists extract DNA samples from skeletons as well as from living people around the world and compare them to show possible migration patterns of different ancient civilizations. Scientists are also able to study inherited diseases such as Alzheimer's Disease. DNA samples are taken from the infected individual's family members, then those samples are examined for chromosomal differences between members without the disease and members who have it. Scientists hope that studying these differences will help uncover the cause of the disease (Meeker-O'Connell, 2004). Additionally, DNA fingerprinting has been used to monitor wildlife. Scientists collect samples of DNA from animals and examine the genetic variation among different populations of a species. When there is little genetic variation in the species we know the species is at risk of extinction. This information helps preserve endangered species (DNA Fingerprinting: Other Uses, 2008).

As will be discussed in detail in Chapters 2 and 5, data protection is one of the main challenges in the field of DNA fingerprinting. In order to ensure that DNA samples are protected, laboratories apply a system of cataloging and storing samples securely. Privacy is also a primary concern. The public is concerned DNA databases violate an individual's right to privacy. However, others argue that convicted felons have fewer rights the moment they commit a violent crime. In addition, many states do not have laws that require destruction of a DNA sample after a conviction has been overturned, so the original DNA sample could in theory be re-analyzed not for forensic purposes, but for medical predispositions. Another concern is practicality, as over half a million DNA samples are waiting to be entered into the CODIS system (Human Genome Project Information, 2006). Despite these concerns there is no arguing that DNA fingerprinting is extremely useful in an array of areas.

CHAPTER-1 CONCLUSION

DNA fingerprinting is an integral part of today's society. Since its discovery in the 1980s, DNA fingerprinting has become an extremely powerful tool to convict the guilty, or exonerate the innocent. It is often referred to as the greatest tool in the history of forensic science.

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Chapter 2: DNA Forensics

The presence of DNA fingerprinting in the Judicial System has grown rapidly since the early 1990's. In the past, the process of collecting, preserving, and analyzing DNA evidence was done without care which sometimes allowed the evidence to be dismissed from individual court cases. One of the most famous cases in which DNA mishandling occurred, the O.J. Simpson case discussed in Chapter-4, is said to be the greatest gift to forensic science. If it weren't for the widely known O.J. failure, the organized process that scientists currently use may not exist. The purpose of this chapter is to describe some of the best current methods for handling DNA samples based on years of forensic testing.

Crime Scene Protocol

The most important thing for an investigator upon entering a crime scene is the evidence left behind. It is the investigator's job to gather as much of these clues as he/she can to deduce what happened at the crime scene. Investigators can form a logical plan for examining a scene with information received from witnesses, victims, detectives, and first responders. Having such information alerts an investigator to key evidence like a shoeprint or trace evidence. Upon arriving at a crime scene, the investigator conducts an organized approach for collecting and preserving potential evidence (Schiro, 2001).

Multi-level containments are put into place that protect a crime scene from on lookers and prevent evidence from being damaged (see Figure-1). The three levels, beginning at the scene and layering their way outward, each serve a purpose. Crime scene tape and police officers are examples of the first level. This is the most common level used by investigators. This

level protects areas where possible evidence may be, as well any entrances that may have been used by suspects. The secondary level, serves as a buffer zone for the crime scene (Dagnan, 2006). Expanding the barrier a small amount allows for a “safe area” where investigators can gather their thoughts and discuss with others without affecting the evidence (Layton, 2004). Having a crime scene log to record who enters the first level is kept here. The log may also be used to record who is present in the second level. The second area also allows for storage of desks or tables to be used by police officers as well as a place for the working personnel to take breaks. The last level of containment, the third, is created by vehicles surrounding the secondary level tape. Used for large cases such as homicides, a perimeter is formed to block roads, traffic, media trucks, and civilians. At least two levels of containment should be used to secure a scene (Dagnan, 2006). With a secure scene, an investigator should examine it in a slow manner. However, crucial evidence may be destroyed as time passes, so rapid decisions must be made (Schiro, 2001).

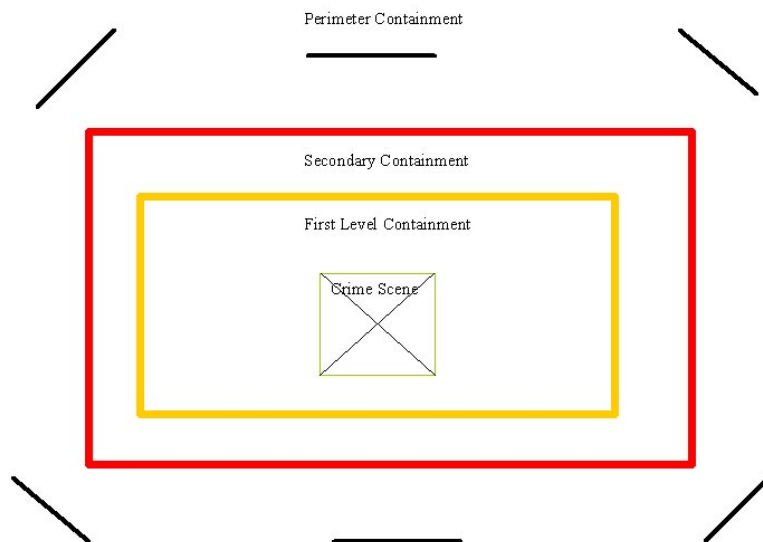


Figure 1: Diagram of Multi-Level Containments Surrounding a Crime Scene (Dagnan, 2006).

To help an investigator remember the scene and to properly document it, many tools are used. The first of which is note taking. Investigators record their actions and the times at which they happened. Note taking is done in chronological order and must contain only facts, no opinions (Byrd, 2000). Included in the notes is who initially contacted the investigator, and other key information until they leave the scene (Schiro, 2001).

A second tool that investigators use is photographs. Before anything is touched, photographs are taken to provide a permanent depiction of the scene. Photographers will take professional pictures capturing different views of the crime scene: an overview, a mid-range, and a close up. The overview encompasses as much area as possible, the mid-range shows the location of evidence relative to other items, and the close-up captures the details of single pieces of evidence (Byrd, 2000; Layton, 2004).

Sketches, or drawings, provide actual measurements of the crime scene. These sketches do not need to be drawn to scale nor do they have to include items that were captured in photographs. The idea is to depict the location of evidence relative to the whole scene by dimensioning to at least two stationary objects (Byrd, 2000; Handbook of Forensic Services, 2007). By dimensioning to at least two objects, investigators can place the evidence in its correct location as it was at the scene. Another advantage is that the same sketch can contain details of several rooms because it is simply how an investigator draws (Byrd, 2000).

A feel for the scene is provided by videotaping. Neither photograph nor sketches, can project the time it takes to maneuver through the scene. With a recording one can walk through the scene in real time experiencing the layout, including possible turns. Another advantage of

video is to reveal something that may have been missed in the photographs or note taking (Layton, 2004).

To begin searching the scene and get an understanding of the crime scene, an initial walk through is done. While walking through, the investigator can form a visual assumption without touching any potential evidence. A second walk through is then performed where the investigator identifies anything that can be used for evidence. After the walk through, it is time to collect the evidence by identifying, documenting, and properly packaging the evidence (Layton, 2004).

Thorough documentation is needed in every aspect of the investigation. In some cases, for safety reasons, this can not be completely achieved, however, it is important to document the scene as close to its original position as possible (Schiro, 2001).

On a walk through, there are many paths an investigator takes, as shown in figure 2 below. Spirals, inward and outward, are useful when only one investigator is present, working toward or away from the center, respectively. In a zone search, the lead investigator assigns other investigators to a specific area of the scene. Switching areas with one another is commonly done as a way of ensuring that the entire scene has been covered. Another pattern, the parallel search, is created by multiple investigators starting at one end of an area and walking toward another in a straight line. Performing two parallel searches perpendicular to one another is essentially creating a grid search pattern (Layton, 2004).

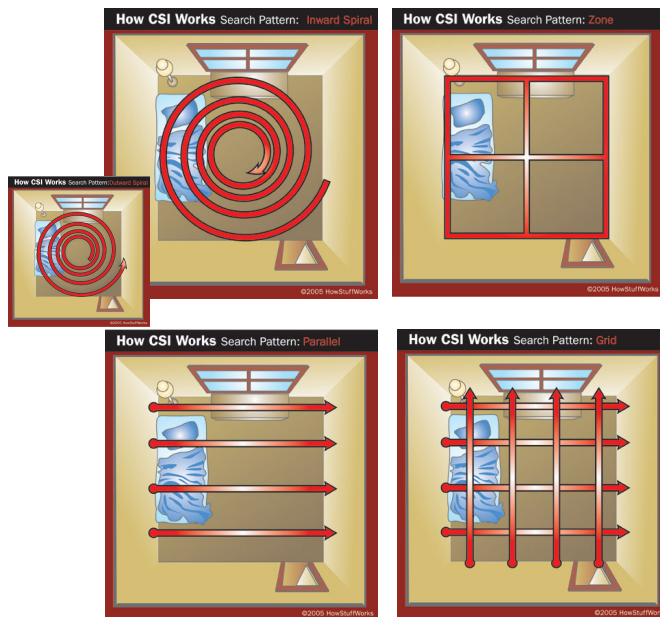


Figure 2: Various Crime Scene Search Patterns Used by Investigators (Layton, 2004).

DNA Evidence

When examining a crime scene, an experienced investigator knows exactly what to look for (President's DNA Initiative, 1999). Finding evidence that will be used to prove the innocence or guilt of an individual in the court room falls upon the investigator (Handbook of Forensic Services, 2007). One of the biggest tools that helps the Judicial System is DNA evidence. DNA is vital to a case; it places a suspect at the scene of crime. To the average person, DNA evidence may be difficult to spot if it does not have much volume. However, an investigator knows that a stain does not need to be visible in order for a few, which is enough, DNA cells to be present (President's DNA Initiative, 1999). Some of the most common sources

of DNA evidence include hair, seminal fluid, saliva, skin, and blood (Byrd, 2000). Table 1 below provides data on how much DNA samples usually contain.

Type of Sample ¹	DNA Content ¹	Common Sources ²	PCR Success Rate ¹
Liquid Blood	20000-40000 ng/mL	Weapon, facial tissue, cotton swab, laundry, fingernail, bullet.	>95%
Blood Stain (1 cm x 1cm)	200 ng		
Liquid Semen	150000-300000 ng/mL	Facial tissue, laundry, used condoms, blanket, pillow, sheet.	>95%
Post-coital Vaginal Swab	0-3000 ng	Victim Sample	
Liquid Saliva	1000-10000 ng/mL	Toothpick, stamp, envelope, cigarette, bottle, glass, can, bite mark.	50-70%
Plucked Hair (with root)	1-750 ng	Suspect Sample	>90%
Shed Hair (with root)	1-12 ng	Hat, bandana, mask, pillow, blanket, sheet.	<20%
Urine	1-20 ng/mL	Suspect Sample, blanket, pillow, sheet	

Table 1: DNA Quantities in Common Samples (¹Kayne and Sensabaugh Jr., 2000; ²President's DNA Initiative, 1999)

Commonly found at the crime scene, blood evidence, as seen by its high DNA content, is extremely helpful to a case. Even before the advent of DNA fingerprinting, crime labs were already using the ABO blood grouping system to narrow down to 4-49% of the human population. Today, scientists analyze blood to narrow the suspect down to one single person, it is highly important that blood as well as all other evidence is handled correctly (Schiro, 2001). As many of us have seen on popular TV shows like CSI or Law and Order, when an individual commits a crime, commonly murder, he or she is likely to try to mop or wash away the blood spatter as if they are getting rid of the evidence. What the suspects do not know is that crime

scene investigation “is based on the notion that nothing vanishes without a trace” (Harris, 1998).

Blood can go unnoticed for years on most surfaces. (Harris, 1998)

Blood visualization enhancing techniques including high intensity light and luminol, a water based chemical, are used by investigators to reveal hidden stains (Schiro, 2001; Harris 1998). Liquid blood can easily flow into hidden areas that a criminal may not suspect, such as floor boards, tiles, carpeting, and cracks. Attempting to clean a stain provides trace evidence turning the blood into a brownish color. High intensity lighting illuminates the crime scene allowing such stains to become visible without damaging the evidence (Schiro, 2001).

When high intensity lighting is not sufficient due to highly diluted blood stains, investigators use a Luminol test to reveal blood stains (Schiro, 2001). When blood is suspected, the investigator sprays Luminol in the suspected areas. When blood is present, the Luminol reacts with hemoglobin, an iron containing protein in the blood, creating a bright bluish-green glow in the dark light (see Figure-3) (Harris, 1998).



Figure 3: Demonstration of the Use of Luminol to Visualize Trace Amounts of Blood. No blood is visible under normal light (left panel), but after spraying Luminol (right panel), the traces of blood glow bluish green (Harris, 1998).

With the use of Luminol, however, come several setbacks. Luminol is used reluctantly as a last resort by many investigators because of its damage to several genetic markers in DNA. Luminol reacts with other products such as bleach. Lab tests will verify the presence of human

blood, but an experienced investigator can distinguish between blood and bleach based on how quickly the reaction occurs. Lastly, because Luminol-treated blood can not be used for DNA fingerprinting, Luminol alone will not solve a case, but it can reveal new valuable evidence including blood splatter patterns, bloody shoe prints, and a point of attack that will aid the investigation (Harris, 1998).

Unlike blood, other body fluids including semen, saliva, and vaginal fluids will glow under UV lighting, without adding Luminol, so special lighting can help locate this type of evidence for DNA analysis without sample destruction. When searching large common areas like bed sheets or a mattress, the use of UV lighting helps an investigator narrow in on the evidence quickly. Similarly, hair can also be spotted on floors or carpets with the use of a powerful white light, some hair may even glow under UV or a strong white light ([Horiba, 2008](#)). But no matter which type of evidence it may be, every sample must follow a precise documented chain of custody.

Chain of Custody

A Chain of Custody form is a written record of any evidence transfers beginning at the crime scene and ending with its final destination, usually a court room. Besides having to travel with the evidence at all times, it is also common to leave a copy of the report in the case folder. Chain of custody forms protect the integrity of collected evidence by containing very specific information (Layton, 2004).

Without proper documentation the origin of DNA evidence is extremely questionable and “will not meet the legal and scientific requirements for admissibility in a court of law.” (Handbook of Forensic Services, 2007). As previously mentioned, this form must remain with

the evidence at all times, and thoroughly document the evidence's travel. When evidence is collected, its location, description, the type of container it is stored in, and whether it was sealed must be written on the form. The description, time, and collectors' information are documented as well. Dates, times, the reason for coming in contact with the evidence, and who it was delivered by are also recorded. Included on the form is also the respective case number. This form must have all this information, to protect the original state of the evidence and to grantee that no one has tampered with it (Schiro, 2001).

EVIDENCE

Agency: _____

Item No.: _____ Case No.: _____

Date of Collection: _____ Time of Collection: _____

Collected By: _____

Description of Evidence: _____

Location of Collection: _____

Type of Offense: _____

Victim: _____

Suspect: _____

CHAIN OF CUSTODY

Received From: _____ By: _____

Date: _____ Time: _____

Received From: _____ By: _____

Date: _____ Time: _____

Received From: _____ By: _____

Date: _____ Time: _____

Figure 4: Example of An Evidence Label. An evidence label, including the chain of custody information (at the bottom) is depicted here (Arrowhead Forensics, Inc., 1998).

Evidence Collection

After proper documentation of the crime scene, the collection process begins (Schiro, 2001). This collection process takes hours of work, and may become tedious, but an investigator must be patient and very careful during the process. A team of investigators need to be sure to gather enough evidence to solidify their case. However, having excessive amounts of evidence to process could cause the lab to become backed up, and this would not be beneficial to any case (Byrd, 2000).

Contamination and degradation are the main concerns when handling DNA evidence. Evidence should be stored in the proper environment. For example, moist evidence should not be exposed to hot and humid environments, since that is where bacteria are prone to grow and could destroy test results. The first step that an investigator can take to prevent contamination is to wear gloves (Reliagene, 2006). While this is done to prevent contamination, it also important for an investigator to protect themselves from possible diseases by wearing gloves, masks, gowns and eye protection whenever necessary (Schiro, 2001).

Body fluids such as blood or semen are found at many crime scenes in the form of stains. Typically two types of stains are found: stains that are dry and normally stuck on a surface, and those that have been absorbed by a medium (Handbook of Forensic Services, 2007). Stains can be found on a variety of surfaces, therefore various techniques exist to collect these stains (Schiro, 2001). When a stain is present, general practice states that it is best to collect the entire object that contains the evidence rather than to remove the stain if possible, for example if DNA containing evidence is located on a gun or an article of clothing, those small objects are usually retrieved intact. However, in some cases an object will be immovable such as a carpet. If a

stain is on a carpet, the stain and a control (an unstained DNA-free sample near the stain) are usually removed by cutting with a clean pair of scissors.

Sometimes a stain is on a surface similar to a concrete floor and can not be removed by cutting. Such stains are collected via extraction, by swabbing or scraping up the stain. Swabbing, the most common method, is done by using a medium. Cotton is the most common material used for collecting a dry stain due to its availability in sterile packages and absorbency, typically in the form of cotton swabs, cotton thread, and cotton squares (Handbook of Forensic Services, 2007).

To collect the stain, an investigator uses as little distilled water possible to moisten the cotton, then places it on a small area of the stain with clean forceps, and waits for the stain to be absorbed. Once absorbed, it is placed in a safe area to air dry, placed into a paper packet and into an envelope (Schiro, 2001). To prevent sample to sample contamination, new swabs are used for each area (Kramer, 2002). If needed, for transportation purposes, the collected evidence may be stored in plastic containers for a maximum of two hours, and must be removed and air dried upon arrival at a secure location (Schiro, 2001).

Other bodily fluids like saliva and urine are also collected by swabbing methods (Handbook of Forensic Services, 2007). Stains that are dry and stuck to surfaces can also be removed by the swabbing method, but depending on the size of the stain, the use of water on the cotton could dilute the sample too much. In this situation investigators use either scraping or tape-lifting because neither technique requires water (Kramer, 2002). In the scraping method, a clean sharp razor is used to literally scrape the sample into a paper packet. Scraping is best used on samples found in the form of crust. Although dilution is not an issue with scraping, it too has

its disadvantages since during collection the stain can be difficult to control, easily becoming flakey and possibly contaminating surrounding areas (Handbook of Forensic Services, 2007).

The other procedure for collecting dry stains, the tape lift, uses conventional fingerprint tape to obtain a sample. The tape is placed sticky side to the stain carefully as to not touch the adhesive while a blunt object (e.g. pencil eraser) is rubbed on the non-sticky side. The stain is then lifted (Schiro, 2001). The advantages of the tape lift include size and shape preservation, and it is a fairly simple technique (Kramer, 2002; Schiro, 2001). Placing the lift sticky side down on a vinyl acetate backing allows the sample to “breathe”, both are then packaged in an envelope (Kramer, 2002; Schiro, 2001).

Many other forms of evidence can be found at a crime scene. It isn't uncommon for an investigator to pick up objects with gloved hands or clean forceps. Picking up cigarette butts, gum, hair, envelopes, or stamps and packaging into proper containers is seen often (Handbook of Forensics Services, 2007).

Packaging

After samples have been collected, it is time to properly package the evidence and send to the lab (Schiro, 2001). Many forms of evidence including swabs, tape lifts, hair and solid objects are stored in paper, the most common material used for packaging (Handbook of Forensic Services, 2007). Clean, unused paper containers are frequently used by investigators. Some of these containers include packets, envelopes, and bags (Schiro, 2001). Due to its porous properties, paper, unlike plastic allows a sample to breathe (U.S. Department of Justice, 2000; Schiro, 2001).

Since bacterial growth occurs in damp areas, moist evidence should never be kept in plastic or paper containers for more than two hours. Bacteria can alter or destroy evidence. Avoiding cross and sample-to-sample contaminations are also an important factor of packaging. If there is a possibility that either type of contamination can occur, samples should be individually packaged in their own containers whether it be paper or plastic (Schiro, 2001).

Liquid samples like blood, urine, semen, saliva, or other bodily fluids should be packaged in plastic tubes called vacutainers (Figure-5). Vacutainers, distinguished by their different color tops, are chemically designed based on the type of sample they will be containing (Schiro, 2001). Blood, for example should be preserved in grey tubes containing sodium fluoride (NaF) (preservative), purple tubes containing ethylenediaminetetraacetic (EDTA) (to prevent coagulation), or yellow tubes containing acid citrate dextrose (ACD) (also for the purpose of anticoagulation). Although plastic is used, the liquid samples remain intact due to the chemical make up of the vacutainers (Kramer, 2002).



Figure 5: Color Coded Screw Cap Vacutainers . These containers are used to collect liquid evidence samples (Arrowhead Forensics, Inc., 1998).

Chapter-2 Conclusion

A forensic scientists' goal is to preserve DNA evidence found at a crime scene so that it will remain uncontaminated and intact enough to obtain DNA data, and whose chain of custody is thorough enough to allow the evidence into a court room. By following correct crime scene

protocols, and maintaining impeccable chain of custody reports, scientists can help assure a sample's acceptance.

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Chapter-3: Landmark DNA Court Cases

Introduction

Forensic science is now an integral part of court cases, but it wasn't always that way. Science was, and is, a growing industry and its involvement in everything we do is constantly changing. Before modern advancements in technology, eye-witness accounts were the most credible evidence for prosecution, but now we have numerous forms of scientific evidence that can be even more accurate than witnesses. But the most recent advances in forensic science are highly technical, and require qualified experts to explain and justify to the criminal justice system. People fear what they do not understand, and correspondingly, updating our laws to keep up with the evolving technology has been a slow process. Deoxyribonucleic acid? Phenolphthalein? Forensic toxicology? Only individuals with some technical background would be able to grasp the concepts involved with today's criminal science and so the interaction between science and law, scientists and lawyers, has been debated for years. The following is a timeline of the debate over DNA's involvement in court cases, beginning with basic non-DNA evidence law and ending with DNA-specific congressional bills. Laws concerning DNA will continue to be refined and updated, but the fact remains, DNA is now a fixture in the courtroom, as a very powerful weapon in a lawyer's arsenal.

Frye v. United States, 1923

While *Frye v. U.S.* didn't have anything to do with DNA specifically, it *did* set a standard for the acceptance of expert testimony in court. In 1923, James Alphonzo Frye appealed a second degree murder conviction because the court had not allowed him to introduce a systolic

blood pressure test (a precursor to the modern polygraph or “lie detector” test) in his defense. Frye claimed that the blood pressure test could prove his truthfulness and overturn his conviction. However, a three-judge court of appeals in Washington D.C. felt otherwise. Even though the conviction held, the court released a two-page opinion which said that any new scientific technique (like the blood pressure test) must be *generally accepted* by the scientific community in order to be introduced in court. Because the blood pressure test did not meet this “general acceptance” standard at the time, it could not be admitted, and the appeal was lost. Also, the opinion stated that it was not enough for one (or several) qualified expert(s) to testify to the validity of a new technique, it MUST be “generally” accepted.

This *Frye* decision is not without its flaws however, as it is somewhat difficult to achieve it in court. The term “generally accepted” itself is up for interpretation, which requires a two-step process. First, determining to which scientific field the technique belongs, and second, determining whether the test is generally accepted by that field. *Frye v. U.S.* has been used to prove admittance of fingerprints, autopsies, blood tests, and later DNA comparisons (there are many other techniques accepted in this manner as well) into court cases.

Federal Rules of Evidence, 1975

The Federal Rules of Evidence (FRE) first began with the creation of a committee in 1965 headed by U.S. Supreme Court Justice Earl Warren, whose function was to create a new standard for admitting evidence that would be easier to achieve than the *Frye* standard. The group of 15 lawyers and legal scholars drafted the FRE to govern the admission of facts which can be used in federal courts to prove cases. While it contains numerous rules, we will focus on Rule 702. Rule 702-Testimony by Experts, states that a qualified witness may be called upon to

understand evidence or determine a fact in issue “if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.” (Federal Rules of Evidence, 1975). This is quite a difference from *Frye v. US* where techniques must be “generally accepted” to be admitted in court. Rule 702 only requires that *one* expert prove that a technique is *reliable*, and the methods were used reliably in this case for it to be admitted.

Downing v. United States, 1985

In 1985, John W. Downing was charged with mail fraud, wire fraud, and interstate transportation of stolen property. Downing was accused of leading a scheme to defraud several vendors by using a bogus company called the Universal League of Clergy (ULC). The government brought in 12 witnesses claiming Downing was the man who had defrauded them (using the name Reverend Claymore). The defense argued that eyewitness testimony was generally unreliable, and asked to bring in a psychologist to refute their testimony. However, the court denied the defense request, ruling the psychologist’s testimony did not meet the “helpfulness standard” of Rule 702. That is, it would not aid the jury in its decision, and may even mislead or confuse the jury instead. Downing was found guilty of mail fraud and wire fraud, but not interstate transportation of stolen property. Downing appealed his conviction claiming that eyewitness testimony is in fact inaccurate. The U.S. Court of Appeals determined that the district court was wrong to exclude the psychologist’s testimony, and remanded the case back to the district court with instructions to conduct an evidentiary hearing on the admissibility of expert testimony. If the district court found the expert testimony should have been included, a new trial should be granted. If not, then the guilty verdict would be reinstated.

After the district court hearing, the court still refused to admit the psychologist's testimony, and upheld the original guilty verdict. The conviction was upheld on the grounds that: (1) the psychologist's testimony did not carry with it a sufficient degree of reliability to aid the jury in reaching an accurate resolution, (2) admitting the evidence would overwhelm, confuse, or mislead the jury, and (3) the expert testimony would not be of value because the eyewitness encounters in this case were numerous and of extensive duration. *Downing v. US* established the standard that when there is any question regarding the reliability of evidence, it is important for the court to conduct an "*evidentiary relevancy hearing*". This pretrial hearing is used to efficiently determine the reliability of evidence.

First Use of DNA Fingerprinting, 1985, U.K.

In the spring of 1985, the first use of DNA identification was reported. A Ghanaian boy had travelled to Ghana and upon his return home to the U.K. was arrested for allegedly having a forged passport. The police believed that he was not the son of a Ghanaian woman who was a citizen of the United Kingdom. Sir Alec Jeffreys (the man who first discovered DNA testing technology) personally performed a paternity test. Having no DNA from the boy's father, Sir Jeffreys used the woman's already accepted three children to reconstruct their father's DNA fingerprint. Using both the mothers and the fathers DNA it was proven that the boy was in fact their son. He was released from custody and allowed to return to the U.K. With its success and along with huge media coverage, it was discovered that thousands of similar immigration cases existed and DNA fingerprinting began to be used on a much larger scale. One year later, it was first introduced into the courtroom.

Colin Pitchfork, 1986

Colin Pitchfork was the first person convicted of murder by way of DNA evidence. He was convicted of raping and murdering two girls, Lynda Mann, 15, in 1983 and Dawn Ashworth, also 15, in 1986 in Narborough, England. The investigation of the crimes revealed that someone with type A blood had committed both crimes. A boy, Richard Buckland, 17, admitted to the killing of Dawn Ashworth, but not Lynda Mann. Having type A blood, local police were convinced that he had killed both girls and contacted Sir Alec Jeffreys to perform DNA testing to prove it. Using the evidence collected and a blood sample from Buckland, Sir Jeffreys concluded that he had not committed *either* crime. Richard Buckland became the first person exonerated through the results of DNA testing. After the trial Sir Jeffreys said " I have no doubt whatsoever that he [Buckland] would have been found guilty had it not been for DNA evidence. That was a remarkable occurrence." (Colin Pitchfork- first murder conviction on DNA evidence also clears the prime suspect, 2007) Upon Buckland's release, the police began a project to collect blood and saliva samples from men in three villages (in total, 5000 men gave samples). They found no matches, but some time later, a man named Ian Kelly was overheard bragging that he had given a sample for his friend Colin Pitchfork. Pitchfork was arrested and, upon comparing DNA, found to be a match to that collected at both crime scenes. On January 23, 1988, Colin Pitchfork was sentenced to life in prison for rape and murder. After the trial Sir Alec Jeffreys said " I have no doubt whatsoever that he would have been found guilty had it not been for DNA evidence. That was a remarkable occurrence."

Andrews v. Florida, 1988

One year later, DNA testing arrived in the U.S. In February of 1987, Tommie Lee Andrews was arrested for rape. He had left his semen at the crime scene, and DNA fingerprinting was applied to the sample. Scientists from Lifecodes Corporation in Valhalla, New York, were able to connect Andrews to the crime through DNA identification. Lifecodes claimed there was a one in ten billion chance that the DNA was not Andrews'. Before the prosecution could use the results of the DNA testing, it had to go through an evidentiary hearing as established by *Downing v. US*. DNA analysis was proved to be scientifically reliable in method, theory, and interpretation, and identified as "generally accepted" by the scientific community. After the long and intense hearing, the judge admitted the DNA evidence into Andrews's trial, but would not permit the statistical evidence that would have guaranteed a conviction. The first trial ended in a hung jury.

Upon retrial, the DNA evidence was again admitted. But this time the court also allowed the statistical data on the grounds of the *Downing* relevancy test and the Federal Rules of Evidence-Rule 702 reliability test. The DNA evidence was also joined by Andrews' traditional fingerprints left on a windowsill, and the victim's facial identification. This time Andrews was found guilty. Tommie Lee Andrews became the first person in the United States convicted of a crime based on DNA evidence. Andrews appealed the verdict, but on November 22, 1988, the original conviction was upheld. Soon after the trial, Andrews' DNA was found to match that found on several other victims, and his prison sentence was upped from twenty-two years for rape, to more than one hundred years for serial rape. Following *Andrews v. Florida*, DNA testing was more easily applied to future cases involving sexual assault and crimes of violence.

People v. Castro, 1989

The first case in the U.S. to seriously challenge DNA fingerprinting admissibility in court was *People v. Castro* in the state of New York. Jose Castro was arrested for the murder of a neighbor and her two-year-old daughter. A crucial piece of evidence was a bloodstain found on Castro's watch. During the pre-trial hearing, the admittance of DNA evidence from the bloodstain was debated. The court determined that DNA identification met the "generally accepted" guidelines from *Frye v. U.S.*, and added in a court opinion that not just the theory, practice and techniques should be evaluated, but also the methodology by which the DNA sample was collected, handled and tested. In the Castro case, it was found that the testing laboratory had not used the proper proven methods for testing DNA samples, and therefore concluded that a full DNA test could not be admitted, but that the sample *could* be used to prove that the blood was not that of Castro.

The case never went to trial as Castro confessed to the murders, but the pre-trial hearing established a three-prong test for allowing DNA as evidence, and also determined that universal laboratory and handling standards must be created. DNA evidence can be admitted through the Three-Prong test if, "(1) DNA identification theory and practice are generally accepted among the scientific community, (2) DNA forensic identification techniques are generally accepted by the scientific community, and (3) Pre-trial hearings are required to determine whether the testing laboratory's methodology was substantially in accord with scientific standards and produced reliable results for jury consideration" (The DNA Wars Are Over, 1996). In addition, proper laboratory methodology is to be determined through the FBI's "Technical Working Group on DNA Analysis Methods" (TWGDAM) validation guidelines established in 1991. The guidelines

encompass all aspects of DNA collection, handling and testing. Though they have been revised twice, in 1995 and 2003, these guidelines are still used in today's trials.

Two Bulls v. United States, 1990

Matthew Sylvester Two Bulls was arrested for the rape of a fourteen-year-old girl at the Pine Ridge Indian Reservation in South Dakota in 1989. Semen was lifted from the girls' underwear and tested for DNA. In the pre-trial hearing, upon hearing the expert testimony of the government's first witness, it was established that the DNA evidence could be admitted because it passed the three part test found in the Federal Rules of Evidence (FRE)-Rule 702 (that it passed the "reliability" test). Two Bulls pled guilty and was sentenced to 108 months in prison. In his appeal, Two Bulls argued that the court had not granted him due-process by determining DNA admissibility through the somewhat lenient FRE-Rule 702, and not by using the stricter "generally accepted" test established in *Frye v. U.S. People v. Castro* was also cited, with its more stringent Three-Prong test. It was determined by the court that by using Rule 702, the *Castro* ruling had been neglected, since no evaluation of laboratory methodology had ever occurred. It also found that *how* the DNA evidence was to be used in the trial should be considered as well. If it is to be used to cause prejudice and not simply as factual scientific evidence, then it should not be admitted. In the end, the Two Bulls conviction was overturned and a new *Five-Prong test* was suggested for DNA admission. The new test suggested that a pre-trial hearing must decide "(1) whether DNA evidence is generally accepted by the scientific community, (2) whether the testing procedures used in this case are generally accepted as reliable if performed properly, (3) whether the test was performed properly in this case, (4) whether the evidence is more prejudicial than probative in this case, and (5) whether the statistics

used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under FRE-Rule 403” (US v. Two Bulls, 1989). Rule 403 states that if evidence is meant to cause “unfair prejudice, confusion of the issues, or misleading of the jury, or by considerations of undue delay, waste of time, or needless presentation of cumulative evidence” then it may be excluded. U.S. v. Two Bulls brought together a number of previous rulings to create a more definitive ruling on admitting DNA profile evidence.

Miles v. Illinois, 1991

In 1991, an Illinois man, Reggie Miles was convicted of rape. His DNA was found to match the DNA found at the crime scene by Cellmark Diagnostics, a major player in the DNA identification field. After his conviction, Miles appealed, arguing that the prosecution had not proved that the techniques used by Cellmark were reliable. However, Cellmark was able to produce accurate statistics and documents to prove that it had followed all TWGDAM guidelines while performing comparison tests in the *Miles* case. The appeal was denied and showed that TWGDAM and the five-prong test were reliable. *Miles v. Illinois* gave a big boost to the public’s confidence in DNA profiling.

Daubert v. Merrell Dow Pharmaceuticals, 1993

Following the case between Jason Daubert and Eric Schuller v. Merrell Dow Pharmaceuticals Inc., on June 28, 1993 the United States Supreme Court released an opinion on how federal judges should decide whether to allow expert testimony into the courtroom. Daubert, Schuller and their parents sued Merrell Dow, claiming that the drug Bendectin had caused Jason and Eric to be born with birth defects. Merrell Dow produced numerous studies

showing that Bendectin did not cause birth defects, while Daubert and Schuller introduced studies showing that it did in fact cause harm. However, the studies that Daubert and Schuller introduced were performed on animals using techniques not yet “generally accepted” by the scientific community. Until then, Judges had used two standards to determine admissibility of evidence, 1) relevance (if the evidence was pertinent to the case and if it would help or hinder the jury) and 2) Frye (if the methods were generally accepted). *Daubert v Merrell Dow Pharmaceuticals Inc.* sought to clarify these standards. The opinion stated that judges should act as “gatekeepers” to examine evidence and methods, and admit only evidence which is both “relevant and reliable, “ effectively giving judges the final say on whether evidence is admitted. This *Daubert Standard of Evidence Admissibility* is based upon expansion of the FRE Rule 702 and states that a judge must determine:

1. Whether the theory or technique has been tested?
2. Whether the theory or technique has been subjected to peer review and publication?
3. Whether the theory or technique has a known or potential rate of error.
4. Whether the theory or technique has standards for controlling the technique’s operation.
5. The degree to which the theory or technique has been accepted in the relevant scientific community.
6. The judge must then also determine whether the expert will be testifying “to scientific knowledge that will assist the trier of fact [judge] to understand or determine a fact in issue,”

The case was sent back to an appeals court to determine if Daubert and Schuller could introduce their evidence under the new *Daubert* standard. It was found that the animal studies still could not be admitted and the suit was thrown out. The Daubert case finally established that the Federal Rules of Evidence supersede *Frye v US*. The Daubert standard has been applied to DNA evidence since 1993.

Paul Eugene Robinson, 2003

In 1993 and 1994, a series of sexual assaults occurred in the Cal Expo area of California. Following six years of investigating, no suspect emerged. So with the 6 year statute of limitations approaching, the Cal Expo district attorneys filed a “John Doe warrant” on the person to whom the DNA profile belonged that was collected from the rape evidence. This was a highly unusual procedure since warrants usually contained a person’s name, age, photo, and last known place of residence.

In 2000, a \$50 million grant from the California state Office of Criminal Justice Planning had been distributed to police departments around the state to do DNA testing on old rape cases. When Paul Eugene Robinson committed a crime in 2003, his DNA profile was entered into the database, where it matched evidence from the Cal Expo victims. In 2003, Robinson was convicted on five counts of sexual assault. If investigators had not run the then unidentifiable DNA samples, Robinson would have never been caught for the earlier crimes, and the rape cases would have been closed due to the statute of limitations law, which allows a case to stay open only for six years. Robinson’s convictions showed the effectiveness of DNA databases and how DNA fingerprinting could be used to resolve “cold cases” from many years prior.

DNA Fingerprint Act of 2005

The DNA Fingerprint Act of 2005 is a recent bill enacted by Congress which authorizes the attorney general to: “(1) collect DNA samples from individuals who are arrested or detained under U.S. authority; and (2) authorize any other federal agency that *arrests or detains* individuals or supervises individuals facing charges to collect DNA samples” (Library of Congress, DNA Fingerprint Act of 2005). This means that every person *arrested* in the United

States can be asked to give a DNA sample to be added to the National DNA Index System (the federal DNA database), unless that act is prohibited by an individual state. While many see this as an invasion of privacy, collecting samples from so many people may allow numerous unsolved cases to be finally resolved.

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Chapter-4: Sensational DNA Court Cases

Introduction

Recently, DNA fingerprinting has been getting more and more media attention. Court cases, paternity tests, and individual identification seem to be getting the most airtime. DNA has been called upon to solve numerous disputes and in doing so, it has become a household name. Like Iraq or Rachel Ray, hearing the phrase DNA when talking about a murder or rape no longer perks your ears up. Media coverage has brought both good and bad publicity, but no matter how it traveled there, DNA has arrived to the mainstream. The following are a few of the instances where DNA has been in the spotlight, although such sensational cases may not have set any new legal precedents.

Bill Clinton and Monica Lewinsky, 1998

On January 21, 1998, The Washington Post broke a story claiming that President Bill Clinton had had an affair with a 22-year-old White House intern, Monica Lewinsky. Over the next several months, the media debated whether the allegations were true. Clinton continually denied the affair, and Lewinsky even signed an affidavit denying the relationship. However, Lewinsky's friend, Linda Tripp came forward with tapes containing telephone conversations in which Lewinsky admitted to having an affair with the president and to having a dress with semen stains on it. Upon turning the dress over to investigator Kenneth Starr, the DNA evidence was collected from the dress stain. The profile matched Clinton and forced him to admit in a taped grand jury hearing that he had in fact had an affair with Monica Lewinsky, contrary to earlier testimony.

Because of the discrepancy in testimonies, Republicans in Congress believed Clinton's false testimony while under oath was an impeachable offense. The House of Representatives voted to impeach President Clinton, but after a 21-day trial by the Senate, Clinton was acquitted of all charges. Clinton was fined \$90,000 for giving false testimony, and his license to practice law was suspended by the U.S. Supreme Court. He remained in office but the very public scandal brought a very negative light upon the remainder of his presidency.

O.J. Simpson, 1994

On June 12, 1994, Nichole Brown Simpson (O.J. Simpson's ex-wife) and her friend Ronald Goldman were found dead at Brown's home in Los Angeles, California. Simpson, a retired football player in the National Football League, was suspected of the murders and asked to turn himself in. Instead, Simpson's attorney read a letter to the media that sounded like a suicide note. Immediately, both police and the media began searching for Simpson. He was spotted in a white Ford Bronco driven by friend Al Cowlings, who later said that Simpson had had a gun to his own head. The infamous "slow-speed chase" chugged along at 35 miles per hour until reaching Simpson's home in Brentwood, California, 50 miles away. O.J. Simpson surrendered to authorities without any more incidents.

A grand jury tried to determine whether to indict Simpson for the two murders, but was dismissed when two of the jurors sold their stories to the media. A California Superior Court judge ruled that there was enough evidence to charge him with double murder. Simpson pleaded not guilty. The 134-day trial, known as the "Trial of the Century", had 150 witnesses, and examined every bit of evidence, from DNA fingerprinting to shoeprint analysis. Simpson's "Dream Team" of lawyers, headed by Johnnie Cochran was able to refute almost all of the

evidence, citing sloppy police work and the possible planting of incriminating evidence. For example, the lab technician in charge of testing a sample of Simpson's blood later testified that he had accidentally left the vial of blood in his pocket for two whole days before performing the DNA comparison tests. A police officer testified that he had seen members of the media tampering with the crime scene as well. After an eight-month trial, it took only three hours for a jury to find O.J. Simpson not guilty. Although the DNA evidence had positively identified Simpson as the murderer, because of mishandling the evidence could not be used to convict, a big blow to public confidence in DNA testing.

Innocence Project

As stated on its website, "The Innocence Project is a non-profit legal clinic affiliated with the Benjamin N. Cardozo School of Law at Yeshiva University, and was created by Barry C. Scheck and Peter J. Neufeld in 1992. The project is a national litigation and public policy organization dedicated to exonerating wrongfully convicted people through DNA testing and reforming the criminal justice system to prevent future injustice" (Innocence Project, 2008). To date, The Innocence Project has freed 218 people in the United States, who each spent, on average, 12 years behind bars. Project Innocence also works to remedy problems within the justice system. "The Innocence Project has forged a national program of sweeping and sustained initiatives to affect legislation and policy at the local, state, and national levels. The Innocence Project advocates for access to DNA testing and the preservation of evidence; independent audits of crime labs, and the establishment of professional standards; reform in eyewitness identification techniques; and also for legislation to compensate the wrongfully convicted" (Innocence Project, 2008). Hopefully, programs like Project Innocence and the criminal justice

system can work together to improve upon DNA fingerprint techniques and to establish highly reliable methods of DNA use in court cases, so that no more innocent people go to jail.

JonBenet Ramsey, 1996

On December 26, 1996, Patsy Ramsey discovered that her daughter JonBenet was missing from their Boulder, Colorado home, and a ransom note was left on the staircase. It said that if \$118,000 were delivered, JonBenet would be returned. John Ramsey made arrangements to pay the ransom. Later that afternoon, upon searching the home, JonBenet's body was found in the basement wine cellar. An autopsy showed that the little girl had been strangled to death. The autopsy also showed that JonBenet had eaten pineapple shortly before her death. The Ramsey's denied ever giving the six-year-old any pineapple, but a police photo showed a bowl of pineapple on the kitchen table with a child's spoon in it. John and Patsy Ramsey were immediately suspected of the murder.

In 2003, police were able to collect enough DNA from JonBenet's body to perform a comparison. It belonged to an unknown male. In 2006, a man name John Mark Karr was arrested in Thailand after he was tracked down for sending emails about the JonBenet case to a University of Colorado professor. He confessed to killing the girl, but his DNA did not match that of the killer, and no evidence existed placing him at the crime scene. John Karr was released and the case remains unsolved.

However, in July of 2008, the Boulder District Attorneys office publicly apologized to the Ramsey family, stating that new DNA testing techniques had ruled out anyone in their family as being the killer. The statement also said, "DNA is very often the most reliable forensic evidence we can hope to find, and we rely on it often to bring justice to those who have

committed crimes” (Letter from DA to John Ramsey, 2008). The DNA evidence found on JonBenet’s body is run weekly through the CODIS database, the FBI’s *Combined DNA Index System*, in the hopes that her killer will someday be brought to justice.

Anna Nicole Smith

In early February 2007, former Playboy 1993 Playmate of the Year and model Anna Nicole Smith was found unresponsive in her hotel room in Hollywood, Florida and later declared dead at a nearby hospital from a drug overdose. Upon her death, a number of legal battles began, including a paternity test to determine the father of Anna’s daughter Dannielynn. Whoever was the father would inherit Anna Nicole’s estate. Four men, Larry Birkhead (Anna’s ex-boyfriend), Howard K. Stern (not the radio personality, but Anna’s lawyer and boyfriend at the time of her death), Mark Hatten (another ex-boyfriend), and Frederic Prinz von Anhalt (husband to actress Zsa Zsa Gabor, who said he had had an affair with Smith) all claimed to be the father of Dannielynn. On April 10, 2007 DNA testing showed that Larry Birkhead was the father. The custody of Dannielynn has yet to be resolved, but Birkhead has inherited Anna Nicole’s real estate, valued at 1.8 million.

King Tut

The mystery surrounding King Tutankhamen (arguably the most famous of Egypt’s Pharaohs) has always been exciting. Why was such a young boy made ruler of Egypt (at age 9)? Why and how did he die? Did he have a son? The last question was partly the reason that in 2000 (after the Egyptian government *finally* allowed it), DNA samples were taken (by an all Egyptian team, per the government’s request) from the mummy to try to determine his lineage.

Scientists plan to compare the sample to others taken from a number of other Egyptian mummies. In August of 2008, DNA tests of mummified fetuses found in Tut's tomb were also performed in order to determine if they were related to the boy king. Results of the 3000-year-old paternity test have yet to be released.

Ted Williams

Two days after Hall of Fame baseball player Ted Williams' death in July of 2002, his body was shipped to the laboratories of Alcor Life Extension Foundation in Scottsdale, Arizona. Apparently, on a food-stained napkin, Williams, his son John Henry Williams, and his daughter Claudia all agreed to be cryonically frozen after their deaths, in the hopes that in the future, medicine and technology will allow them to "live again" by transferring their DNA, head (including brain), and skin into a host body, allowing them to "live forever." Ted Williams' eldest daughter, Bobby-Jo Williams Ferrell, accused her brother of forging the agreement in order to sell their father's DNA. She also pointed out that in his will, Ted had arranged to be cremated and his ashes scattered off the Florida coast. However, a court ruled that because the date on the so-called napkin agreement was after the will was drawn up, the body of one of the greatest baseball players of all time was to be frozen. In 2004, John Henry Williams died of leukemia and his body was brought to Alcor Life Extension Foundation in accordance with the napkin agreement. Recently, in an interview with Sports Illustrated, Alcor chief operating officer Larry Johnson admitted that 8 of the 182 samples of Ted Williams' DNA had gone missing in 2003, further fueling speculation that his son had been selling his DNA to the highest bidder.

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CHAPTER-5: DNA DATABASES

DNA databases are one of the most controversial topics in DNA fingerprinting. A DNA database is a collection of DNA profiles on a computer used to compare a single DNA fingerprint against a large number of DNA samples. Many people believe that DNA databases help make the society we live in safer. Others, however, feel that they represent an invasion of privacy. This chapter will discuss DNA databases, why we need them, and their ethics.

CODIS: The World's Largest DNA Database

The Combined DNA Index System (CODIS) is the world's largest DNA database. The CODIS program began in 1990 with only twelve forensic laboratories. Today, CODIS has approximately 153 participating laboratories across the United States, and has assisted over 4,719 investigations (Adams, 2002). The CODIS database utilizes two indexes to investigate crimes where DNA samples are recovered from the crimescene. DNA samples of individuals who have committed sexual or violent offenses are placed into the *Convicted Offender Index*. DNA samples recovered at a crime scene are placed into the *Forensic Index*. CODIS then searches these indexes for matching DNA profiles (Brown et al., 1995).

The FBI's CODIS database currently allows data from 13 core STR loci, discussed in Chapter-1 (CODIS STR, 2006). "The STR loci approved for use in CODIS were specifically selected as law enforcement identification markers because they were not directly linked to any genetic code or medical condition" (Adams, 2002).

CODIS was implemented as a distributed database with three levels: local, state, and national. All three tiers contain the forensic and convicted offender index, and the population database file. The Local DNA Index System (LDIS) is installed at crime laboratories operated

by police departments or other state agencies. All forensic DNA records originate at the local level and are transmitted to the state and national levels. Each state participating in the CODIS program has a State DNA Index System (SDIS) that enables exchange and comparison of DNA profiles within a state. SDIS also links the local and national levels, and is typically operated by the agency responsible for maintaining a state's convicted offender DNA database program. The National DNA Index System (NDIS) is a single central repository of DNA records submitted by participating states, and is administered by the FBI. NDIS allows forensic laboratories throughout the United States to share and exchange DNA profiles (Brown et al., 1995).

The need for standardized quality assurance protocols came with the introduction of CODIS. The Technical Working Group on DNA Analysis Methods (TWGDAM) formed following the *People v. Castro* case (1989) discussed in Chapter-3, and developed guidelines for quality assurance. Today there are two sets of quality assurance standards, *Quality Assurance Standards for Forensic DNA Testing Laboratories*, and *Quality Assurance Standards for Convicted Offender DNA Databasing Laboratories*. In order for a laboratory to be able to upload their DNA convicted offender, casework, or missing person data to the National DNA Index, they must first agree to abide by these quality standards. Audits are also performed on participating laboratories to ensure compliance (Adams, 2002).

Whose Information Is Entered into Databases?

The laws authorizing DNA collection vary from state to state (Table 1). Currently, all 50 states require convicted sex offenders to provide a DNA sample, and 46 states require all convicted felons to provide a DNA sample (National Conference of State Legislature, 2008). Some states are even beginning to authorize *arrestee* sampling. In 2003, Massachusetts State

Governor, Mitt Romney signed a bill requiring all *convicted* Massachusetts felons to submit DNA samples. This bill specifically states:

"Any person who is convicted of an offense that is punishable by imprisonment in the state prison, and any person adjudicated a youthful offender by reason of an offense that would be punishable by imprisonment in the state prison if committed by an adult shall, within 1 year of such conviction or adjudication, submit a DNA sample to the department, which shall be collected by a person authorized under section 4, in accordance with regulations or procedures established by the director" (Massachusetts General Laws, 2003).

Table 1: List of the Different States and Their Laws Authorizing DNA Collection. Please note this is a portion of a larger table that shows all 50 states (National Conference of State Legislature, December 2005).

State	All Felonies	Some Juveniles	Some Misdemeanors	Some Arrestees	Not Guilty By Mental Defect or GBMI	Other
Louisiana	X	X		X -- Authorized to extent funding is available.		
Maine	X	X	(May include a lesser included offense if a qualifying offense was originally charged.)			Includes all Class A, B, C serious crimes and Class D and E convictions if the person had prior felony conviction for which DNA not collected.
Maryland	X	X				Includes some misdemeanors.
Massachusetts	X	X				

What Are DNA Databases Used For?

Cold Cases

DNA databases are often used to aid in solving "cold cases". Cold cases are crimes where there is DNA left at a crimescene, but there is no suspect. Convicted offender databases store thousands of potential suspects DNA samples. DNA samples found at crimescenes can then be compared against these databases. Studies show an individual who has committed a crime is more likely to commit another crime of similar nature than someone who has never committed a crime before. The CODIS database allows DNA samples from crimescenes to be cross-compared. This allows the investigators to link crimes together, which may help lead to the identification of the perpetrator (U.S. Department of Justice, 2002).

Success Story

In 1999, Leon Dundas was killed during a drug deal. The year prior, Dundas had refused to give a blood sample in connection with a rape investigation. Investigators took a blood sample at the medical examiners office and sent it to the DNA lab. Dundas' DNA sample was compared with the national forensic index and matched the DNA evidence from a rape victim in Washington, DC. More DNA evidence was entered from other unsolved rapes, and Dundas' DNA matched seven additional rapes in Washington and three more in Jacksonville, FL. These crimes would never have been solved without DNA (U.S. Department of Justice, 2002).

Probability of a Match

We need databases to better assign probabilities of a DNA match. Each new DNA sample entered into the CODIS database makes it more useful and more accurate. Databases help

determine allele frequencies at specific loci. We then multiply the frequency of locus-1 by the frequency of locus-2 to obtain the overall chance of the match occurring randomly. For example, locus-1 has a frequency of 0.1, and locus-2 has a frequency of 0.15. The probability of a similar match occurring randomly is 0.1×0.15 or 0.015. This means we would expect about 1.5% of the population to have a similar profile. The National DNA Index (NDIS) contains over 6,031,000 offender profiles (U.S. Department of Justice, 2008). Such a large number of profiles allow laboratories to achieve frequencies of about one-in a billion that profiles will have an identical match.

Figure 1 shows an accurate calculation of frequency for four loci. The final analysis allows the assignment of a probability of 0.00014 of a random match. The more accurate the probability of a match, the more likely the data will get accepted into the courtroom. Thus, we need databases to help us assign accurate frequencies to individual loci. DNA databases will help accomplish this by allowing us to test a greater number of people's DNA for precise allele frequencies. "Ultimately, the success of the CODIS program will be measured by the crimes it helps to solve" (U.S. Department of Justice, 2008).

DNA Profile		Allele frequency from database			Genotype frequency for locus		
Locus	Alleles	times allele observed	size of database	Frequency		formula	number
CSF1PO	10	109	432	$p=$	0.25	$2pq$	0.16
	11	134		$q=$	0.31		
TPOX	8	229	432	$p=$	0.53	p^2	0.28
	8						
THO1	6	102	428	$p=$	0.24	$2pq$	0.07
	7	64		$q=$	0.15		

vWA	16	91	428	$p=$	0.21	p^2	0.05
	16						
			profile frequency=				0.00014

Figure 1: Example Calculation of Profile Frequency for Four Loci (Brenner, 2004).

DNA Database Ethics

DNA databases are a powerful tool in law enforcement. The public, however, is concerned DNA databases violate an individual's right to privacy when they are required to donate their DNA. Database proponents argue that convicted felons have *some* rights to privacy, however the felons have *fewer* rights the moment they committed a violent crime. Thus felons may still have the right to be housed in a semi-private facility, but not to withhold their DNA from analysis that could help solve a crime.

Still, many people remain concerned knowing the original DNA sample can be misused. About half of the biological material from a swab is kept by police departments (Steinhardt, 2003). This information could potentially be analyzed and reveal private information. It has also been said that genetic information not only pertains to the individual whose DNA has been sampled, but to everyone who shares that person's blood line. This means potential threats of privacy expand to much of the general public. These concerns would be diminished however if we agree to destroy the original DNA sample after reliable accurate forensic information has been obtained, so no further analysis could be performed.

The public is also concerned that insurance companies or prospective employers will gain medical predisposition information on individuals from the database. But can you really obtain

medical information from a forensic database? This is a topic of much discussion. It is believed that most of a DNA sample is "junk DNA". Junk DNA is a name for the portions of the DNA for which no function has been identified, although scientists might find a function for some of this so called "junk DNA" in the future (Suurkula, 2008). If researchers can find functions for "junk DNA" medical information may be available to insurance companies and employers. But again, this problem would diminish if the original DNA sample is destroyed after obtaining forensic information.

The length of time a DNA sample is kept is also an issue. Some say samples should be kept forever. Others believe the length of time a sample is kept should be proportionate to the crime. Many believe samples should be deleted once an individual is found innocent of an offence. Still, the majority of people think records should be kept up to five years after death (The Reister, 2008).

Although there is so much controversy over DNA databases, the evidence has been critical in convicting thousands of criminals. In Massachusetts alone, over 900 cases have been aided with DNA databases (Figure 2). Without the technology of DNA fingerprinting and DNA databases, many criminals would have gone unprosecuted.

Statistical Information	Total
Offender Profiles	61,073
Forensic Samples	3,274
Number of CODIS Labs	2
NDIS Participating Labs	2
Investigations Aided	926

Figure 2 Massachusetts Statistical Information About DNA Databases (U.S. Department of Justice, 2008).

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CONCLUSIONS

The many applications of DNA fingerprinting have allowed this exciting new technology to become an integral part of today's society. Ranging from molecular archeology and paternity testing to forensics, where it is now most commonly seen, the acceptance of DNA fingerprinting has grown significantly since its first appearance in the mid-1980's.

It is difficult for many to grasp the idea that something so small and invisible to the naked eye could have such a large role in proving one's innocence or guilt in the court room. However, the process of accepting DNA evidence into courtrooms has not been easy, as mentioned in Chapters-3 and 4. Concerns about evidence integrity have often been questioned, and can cause DNA evidence to be dismissed. As we saw with the O.J. Simpson case, a blood sample was improperly stored and was not properly documented with a chain of custody, so evidence tampering became a possibility. When presented in court, there was no way to prove beyond a shadow of a doubt whether the sample had been contaminated.

As DNA fingerprinting technology is more frequently used, its accuracy, when completed properly, is received with less skepticism. In the field of DNA forensics, a standardized procedure for identifying, collecting (including chain of chain forms), packaging, and analyzing evidence has now been created. When this process is performed correctly, the integrity of a DNA sample is maintained, and therefore the chances of an items' admittance in the court room is increased.

When discussing technological advances such as DNA fingerprinting, it is impossible to disregard the ethical issues stemmed from society concerning DNA databases. Databases, like CODIS, the Combined DNA Index System, which contain samples from convicted offenders,

have proven to be a great asset when solving crimes. However, arguments have been made pertaining to a person's genetic privacy. Fears about medical loci being analyzed have been voiced, but there is no proof that any medical predisposition data exist in any of the 13 core loci currently analyzed for CODIS. The 13 core CODIS loci have been very carefully chosen by scientists over the years because they vary between individuals, not because they provide medical information. Although the original DNA sample could in theory be used for re-analysis to determine some medical predispositions, this becomes impossible if the original DNA sample is discarded after obtaining a reliable assay of core information, so the authors of this IQP conclude that many of the privacy rights issues diminish if the original sample is discarded after obtaining a reliable profile from the forensic analysis.

The authors of this IQP also support the vast majority of states that require *convicted* felons to provide DNA samples to CODIS. We do not agree with more controversial positions of *all* individuals providing DNA, or even all *arrested* individuals providing DNA. We conclude that strong oversight of DNA databases is required to prevent information falling into the wrong hands, and it is the government's responsibility to assure society that proper data protection are being followed.