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DNA FINGERPRINTING

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ABSTRACT

This IQP was undertaken for the purpose of using the topic of DNA fingerprinting as an example of investigating the effects of technology on society. Methods for the proper collection and handling of DNA evidence were discussed, as were procedural information for the different types of DNA analysis tests. The prolonged struggle to allow DNA and other complex technical evidence in courts was highlighted through an investigation of several landmark court cases. The capabilities of DNA fingerprinting as a means of solving crimes, even those long since considered cold cases, were highlighted by reviewing a small selection of sensational court cases that involved DNA. The purposes of forensic and medical DNA databases were explained, including a discussion of the issues related to privacy rights. The report culminates in a conclusion by the authors on their findings and beliefs regarding this paramount, yet controversial, technology.

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PROJECT OBJECTIVES

The objective of this paper is to examine the technology of DNA fingerprinting, the methods of collection and storage of DNA evidence, DNA analysis procedures, and the legal and ethical implications of using DNA to solve cases. The paper is written in layman's terms, so that the content may be accessible to a wider audience. The new and emerging field of DNA fingerprinting has changed the legal process profoundly in the last 20 years. These changes are exemplified in several landmark court cases, which will be described and explained in this paper. DNA evidence is so powerful it can be used to solve decades old cases, and a few of these sensational cases will also be discussed in detail. Overall, this project will explain the science and technology of DNA fingerprinting, proper methods for storing and collecting DNA, the technology's role in court, and the ethical dilemmas presented by its use. All of these issues will be explained in language that can be easily understood by laymen, giving the reader a greater appreciation for the uniqueness that DNA gives to each of us, and how law enforcement uses this to aid its struggle for justice.

Chapter-1: DNA Fingerprinting Types

Mark Lerret

DNA fingerprinting is a process by which individual organisms, generally humans, can be identified using their DNA. The technology used in this process has been developed over decades from earlier molecular biology assays, and has greatly changed the way we perform paternity testing and criminal investigations. Recent advancements in this technology give more accurate and reliable results, increasing the credibility in courts. However, the acceptance of complex information in courts is controversial, so this topic provides an excellent opportunity to investigate the impact of technology on society. The purpose of this chapter is to introduce the methods and technologies involved in DNA fingerprinting, and to illustrate the structure and functions of DNA itself.

DNA: Introduction and Terminology

Genetics is the study of hereditary traits and their variation in living organisms. DNA is the molecule that encodes hereditary traits in most living things. DNA itself is the foundation of life, from which all other functions are based. Although DNA has been passing on traits from one generation to the next since life began, we only became aware of its existence chemically in the 1920's, and its structure was determined in the 1950s. Although we were previously unaware of DNA, our ancestors were able to selectively breed crops and animals for optimal quality. They knew very little about the principles that made selective breeding possible, but

through modern science we have come to understand quite a lot about genetics.

The first model of the DNA double helix molecule was published in 1953 (Crick and Watson, 1953; PBS, 1998). The scientists responsible for this model were James Watson and Francis Crick, for whom the model is named. It is commonly known as the double helix, a twisted pair of strands made of sugars and phosphates (**Figure-1**). The two strands are connected by nucleotide base pairings, adenine(A), thymine(T) guanine(G) and cytosine(C). These base pairs are the rungs of the DNA ladder. Each base can only pair up with one other base, adenine with thymine, and guanine with cytosine. Adenine and guanine are known as purines, and thymine and cytosine are known as pyrimidines. Purines are much larger than pyrimidines, therefore two purines cannot bond because they are too large and would destabilize the helix. Likewise, two pyrimidines are too small to bond together. The order of these bases in the DNA molecule constitutes the DNA "sequence", and determines the traits of the organism.

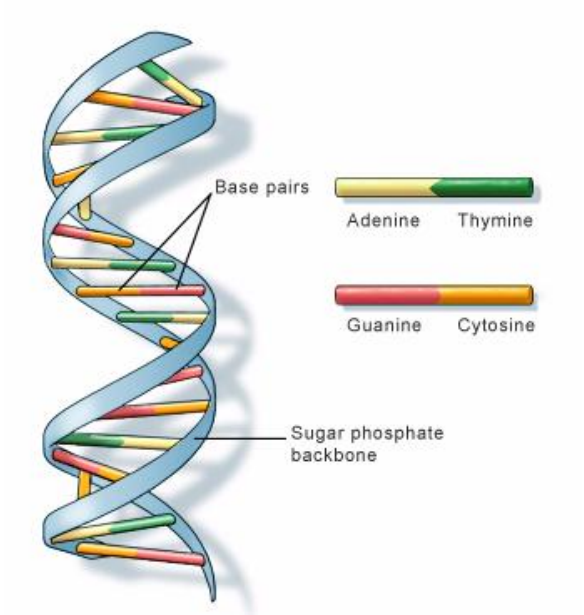

Figure-1: Structure of the DNA Double Helix. Shown is the DNA molecule composed of nucleotide bases (colored rungs of the ladder) and an anti-parallel double helical backbone of sugar and phosphate (blue). (DNA Sequencing Service, 2011)

Nucleotides are composed of bases connected to a backbone of phosphates and sugars. Each base is bonded to its corresponding base weakly to create the rungs of the ladder. There are approximately 3 billion base pairings in the human genome. Human DNA is about 99.9% identical between individuals, a similarity that makes us human beings. But this complex identical sequence initially caused problems for forensic geneticists due to the huge amount of information that had to be sifted to find acceptable genomic markers for unique identification purposes. But as the technology was refined, eventually areas of DNA most likely to be unique between individuals were identified. Examples of some of these processes will be explained in detail in this chapter.

Cells

Cells make up every living organism on Earth (National Center for Biological Information, 2004). Organisms can be unicellular or multicellular, all of which vary greatly in complexity. Single celled organisms were the first living things to appear on this planet, and are very simple compared to multicellular organisms. These cells are called prokaryotic cells, and the organisms are known as prokaryotes. These cells are identified by their lack of a nucleus and nuclear membrane. The best known and most studied prokaryote is bacteria. Cells that have a nuclear membrane are called eukaryotic cells. All multicellular organisms are eukaryotes, and some unicellular organisms are eukaryotic cells.

Mitosis is one of two cell reproduction processes (**Figure-2**). In mitosis, two cells with identical genomes are created. Interphase is the starting point, essentially consisting of the time

between when a cell is created and when it divides into two. This is when the cell is in equilibrium in a sense, when the amount of DNA remains constant, and is being expressed. To begin mitosis, the cell duplicates its DNA and chromosomes (discussed in more detail later in the chapter). It then splits the genetic material into two equal groups, and moves each group into its own side of the cell. Next, the cell breaks apart and two new and identical cells form. This is how prokaryotes and eukaryotic cells multiply. Eukaryotes do this process for multiple DNA molecules packaged as chromosomes.

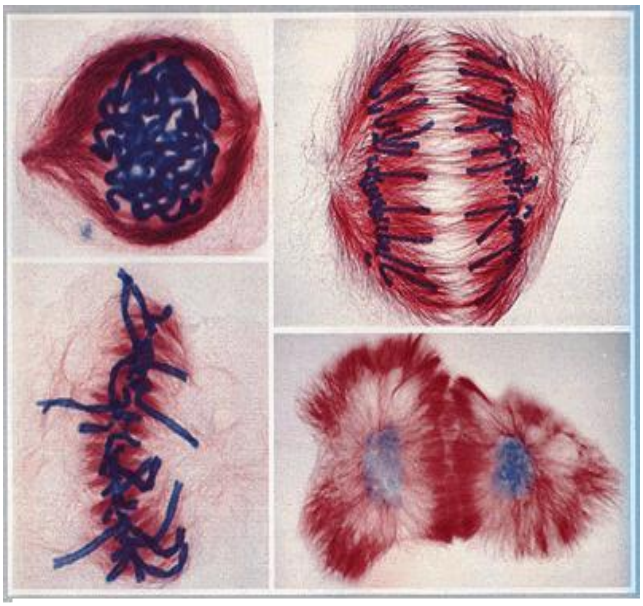

Figure-2: The Phases of Cell Mitosis. Shown clockwise from the upper left are: prophase, anaphase, telophase, and metaphase. (Sage Park, 2005)

Meiosis is a process very similar to mitosis, but has a few distinct differences. Meiosis results in four daughter cells instead of two. This process is used to produce gametes, or reproductive cells (i.e. eggs and sperm). The daughter cells are not exact copies of the original cell, but are based on the genetic makeup of the original. Meiosis is the process that accounts for hereditary variation in offspring. The parent generation produces gametes that have some of

their genetic material, but not enough to create a new organism until it fuses with a gamete of the opposite sex.

Eukaryotic cells have organelles, smaller structures within the cell that perform specialized complicated functions. A few commonly known organelles are mitochondria, the nucleus, and the golgi apparatus. For purposes of our discussion on DNA fingerprinting, the nuclei and mitochondria contain DNA, either of which can be fingerprinted.

In the nucleus, the genetic material is organized into chromosomes. These are structures made of a single strand of DNA wrapped around proteins, which package the DNA and control its functions. Sections of DNA called genes control certain traits of an organism. Genes are made up of codons, groups of three bases that determine which amino acid that will be produced in the protein made from that gene. The sequence of amino acids makes a protein, the molecule that catalyzes most biological processes. An allele is an alternate form of genes. For example, blood type is determined by the alleles passed on from the parents. The possible alleles of blood type are A, B and O. Receiving one of these from each parent decides what blood type the offspring will be.

DNA STRs

Short tandem repeats (STR) are areas of repeating patterns of a base sequence. An STR is a microsatellite, a genetic location consisting of 2 to 13 nucleotides repeated many times in a strand of DNA (DNA Diagnostics Center, 2008). Analysis of an STR eventually illustrates the number of repetitions of a single order of nucleotides in that specific location.

STRs have properties that make them ideal DNA markers to use for DNA fingerprinting. They typically do not encode any proteins, so their DNA sequences vary considerably between individuals. These patterns have among the highest variability of any DNA marker (DNA Diagnostics Center, 2008). Coding sequences are not commonly used for DNA fingerprinting because most genes are conserved between individuals; if those sequences vary much, the gene becomes non-functional. At each locus, one inherits one copy of an STR from each parent, allowing analysis to prove biological relations. STRs are short enough to be easily amplified and copied by PCR (discussed below). Moreover, STR alleles also have a very low mutation rate, making them very stable and predictable for forensic analysis. The STR sequence is usually amplified by PCR, then the size of the amplified product is determined on a gel to determine how many repeats occur at that location.

In the U.S. DNA profiles submitted to CODIS, the FBI's database usually analyze 13 core STR loci (**Figure-3**) (University of Arizona, 2006). These loci have been carefully selected by biological scientists over the years to provide a reliable analysis and whose sequences vary greatly between individuals. When all (or most) of the core loci are analyzed, the patterns can be so variable (polymorphic) that the chance that two people (that are not identical twins) share the same patterns at all 13 selected loci is about 1 in 1 billion. The FBI used the 13 core loci to standardize the collection of DNA for analysis. Analyzing these loci, all forensic labs can create compatible databases and share information with each other more efficiently.

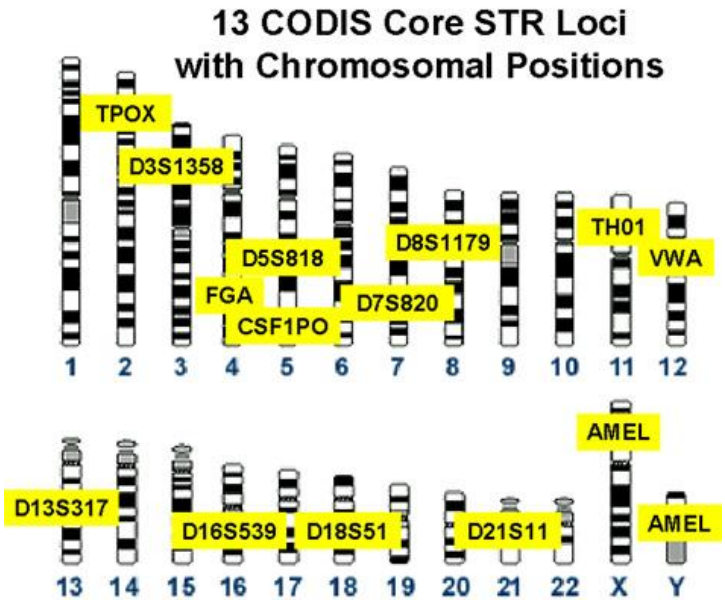

Figure-3: The FBI's 13 Core Loci for STR Analysis. Shown are the 13 core loci (yellow boxes) and their approximate positions on the human chromosomes, and two sex loci AMEL boxes (lower right). (National Institute of Standards, 2011)

DNA VNTRs

Variable numbers of tandem repeats (VNTRs) is another term used to describe variations in DNA sequences between individuals in which a relatively short nucleotide sequence is repeated many times. The length of a typical VNTR pattern varies from 6 to 100, and can span anywhere from 0.5 kb to several kilobases (kb) (Chantler, 2004). VNTRs are typically longer than STRs, and are difficult to amplify by PCR. The discovery of VNTRs paved the way for DNA fingerprinting, and these repeats were the first ones analyzed by Alec Jeffreys.

Although VNTRs cannot usually be amplified by PCR, other assays were developed to characterize them even before PCR was invented. VNTRs can be excised from their surrounding DNA by restriction enzyme digestions. Once they are excised from the genome, their location is

determined by hybridization to a complementary probe, and their size determined by gel electrophoresis. Because VNTR analysis is more labor intensive than STR analysis, usually STR analysis is applied first to a forensic sample. But STR analysis is prone to contamination, so VNTR analysis is used if time allows and the DNA is of a sufficient amount.

After analysis, the VNTR pattern looks like a bar code, and if the band sizes match the DNA samples are related. Therefore, two forensic samples left by the same person show the same pattern when analyzed. This is the basis for VNTRs use in forensics. In addition, the rules of inheritance apply to VNTRs. That is, an individual inherits one from each parent, and the genome reflects this rule.

Repeat sequences shorter than STRs and VNTRs exist, but are not typically used in forensics. Very short dinucleotide repeats are usually too unstable to perform useful analysis; di-nucleotide repeats vary in different kinds of tissues is an individual, and tri-nucleotide repeats vary from one generation to the next.

Brief Genetics History

In the 19th century, Gregor Mendel, a Moravian monk, first observed the passing of traits from one generation of organism to the next (Yon, 2011). He did this by growing many generations of pea plants, and observing the differences and similarities between parents and offspring. This is regarded as one of the great discoveries in the history of science, and began the branch of science now called genetics. Since then scientists have made extraordinary discoveries about DNA, its replication, inheritance, expression, and modification.

The 1950's were a time of great discovery in the science of genetics. The chemical structure of DNA was discovered, creating a new discipline of science called molecular biology that eventually allowed the DNA sequence to be cloned and manipulated. These discoveries set the foundation for many other fields of science related to genetics. The genetic code was discovered in 1966, giving scientists insight as to how DNA translates into proteins in the human body. This new discovery allowed scientists to make predictions about human characteristics by studying DNA, and set the foundation for the development of fields such as genetic engineering.

Perhaps the culmination of all previous genetic work was the beginning of the human genome project. This massive initiative was initially begun by the US Department of Energy and the National Institute of Health in 1990, and had later contributions from the United Kingdom, Japan, France, Germany, China and other nations (US Department of Energy, 2008). The goal of the project was to sequence all 3 billion bases of the human genome. The project, completed in 2003, has huge implications for the future of genetics and many related sciences.

DNA Fingerprinting History

The major breakthrough for DNA fingerprinting came in 1985 from Dr. Alec Jeffreys of the United Kingdom (Jeffreys et al., 1985a) who adapted the Southern blot assay invented in 1975 (Southern, 1975) to an analysis of DNA differences in humans. The Southern blot assay was designed to identify a specific DNA fragment from within a complex mixture of fragments by hybridizing the mixture to a specific DNA probe that base-paired with the corresponding fragment to identify it. The Southern blot was initially applied to identifying viral DNA

fragments (Southern, 1975). When first using his new modification, Jeffreys in an effort to determine the maternity of a Ghanaian boy immigrating to the United Kingdom with a suspicious passport, performed a historic experiment (Jeffreys et al., 1985b). The results of the DNA experiment showed not only that the boy was the son of the woman in question, but that all of the woman's children had the same father. Since this first application, DNA fingerprinting technology has been improved over many years.

DNA Fingerprinting Methods

RFLPs

Restriction fragment length polymorphism (RFLP) is a method of DNA analysis that molecular biologists use to find similarities in DNA. This is the method originally modified by Dr. Jeffreys in 1985 (Jeffreys et al., 1985a), and it quickly became the early standard for DNA testing. As discussed above, this method was derived from the earlier Southern blot technique (Southern, 1975). An RFLP is a sequence contains a specific target sequence flanked by restriction sites on each end. The DNA is cut with restriction enzymes, releasing all fragments flanked by that particular DNA sequence (**Figure-4**). The DNA fragments are separated by size by electrophoresis (Diagram upper left), then the fragment pattern is blotted to a membrane to allow probe hybridization (diagram upper center) (Department of Biology, 2001). A single-stranded probe complementary to a specific VNTR sequence of interest is then hybridized to the DNA fragments on the membrane (diagram lower). If the probe hybridizes to a fragment, the

fragment's position becomes visible on x-ray film (yellow panel, left).

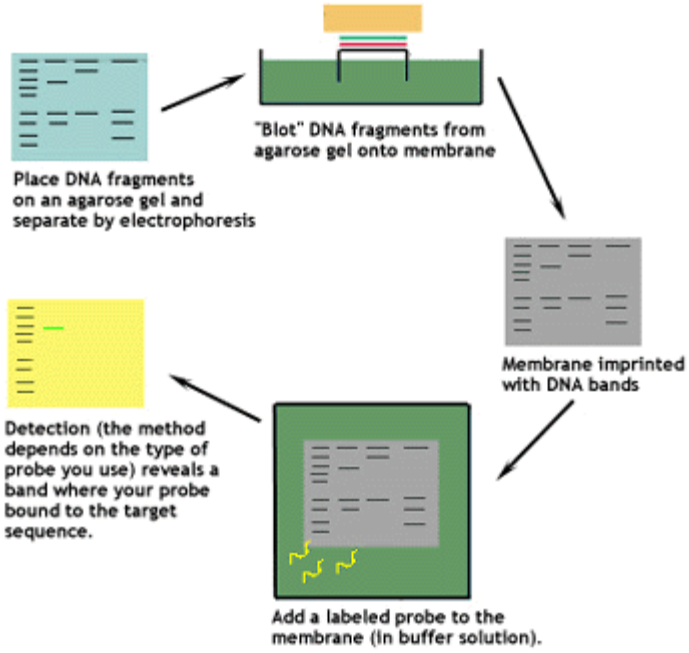

Figure-4: Diagram of a Southern Blot. In this process, DNA fragments are separated by size (upper left panel), blotted to membrane (upper center panel and right pane), and hybridized to a probe (lower panel) to visualize one specific DNA fragment within the complex DNA mixture (yellow panel left, green band). (Blog Images, 2011)

As an example of an RFLP assay, consider the target strand of 20 bases GAATTC-GCATGCATGCATGCATGCAT-GAATTC whose sequence is flanked on each side by the short sequence GAATTC. GAATTC is recognized and cut by the restriction enzyme EcoRI, so cutting DNA with EcoRI releases this fragment (and others) from the DNA molecule. To locate this specific fragment, the membrane would be hybridized to a probe with the complement sequence so base-pairing would occur. DNA tested this way is represented visually by a bar

code identifying multiple fragments simultaneously. The bands have sizes that range from a few hundred to a few kilobases (thousands of bases).

The RFLP method of DNA analysis has been used historically to help identify the sickle-cell mutation in which both alleles encoding hemoglobin contain the code for the wrong amino acid (Kimball, 2011). The only difference between normal hemoglobin and sickle-cell disease is one base, the substitution of a T for an A in the middle of codon 6. This base is in the middle of a sequence that can be cut by an enzyme. When a normal hemoglobin gene is digested by this enzyme, the restriction enzyme cut will occur, and the fragment will be cut out. If a sickle cell gene is digested, the cut cannot occur at this point and the resulting fragment is longer. The test to determine whether a patient has sickle-cell disease shows whether the short fragment or long fragment is made when using the DNA of that patient. DNA is collected and treated with the enzyme, then electrophoresed to determine the size of the fragment. This device puts the test DNA next to a control sample in a gel. Electric current is run through the gel, causing the two samples to move. The control sample moves a certain distance, representing the length of a fragment from a normal gene. The patient sample will move the same distance if it is healthy, but will move less if it is not. It is harder to move the longer fragment through the gel, so it will fall short of the control DNA. This determines if the patient has the gene for sickle-cell disease.

RFLP testing has many other applications. A couple may wish to find what diseases a child of theirs may be vulnerable to, knowledge that could be very important in their decision to have children. This method of testing can also be used to discover or strengthen a diagnosis of a patient with sickle-cell disease or other diseases. RFLP testing is a non-amplifying DNA test; it

does not use PCR. This means it requires a relatively large amount of DNA, so is reserved for forensic samples containing sufficient DNA. However, the test is very resistant to contamination, resulting in more reliable results, so scientists prefer to run it if time and DNA allows. Because the PCR-STR test is more rapid, it is often run first.

PCR-STR Analysis

The current most common method for genetic mapping is the polymerase chain reaction (PCR) technique applied to short STR repeat sequences. PCR can create billions of copies of a target sequence in a short period of time, often just a few hours (**Figure-5**). The process requires only a small amount of DNA, sometimes even from one cell, which is submerged in a solution containing several types of reagents. The most important of these molecules is the target strand of DNA, in our case a STR sequence. The reaction also contains free nucleotide bases (deoxynucleotide triphosphates, dNTPs) to incorporate into newly replicating DNA molecules, heat-stable Taq polymerase to catalyze DNA synthesis, and two short DNA primers to initiate DNA synthesis flanking the STR of interest.

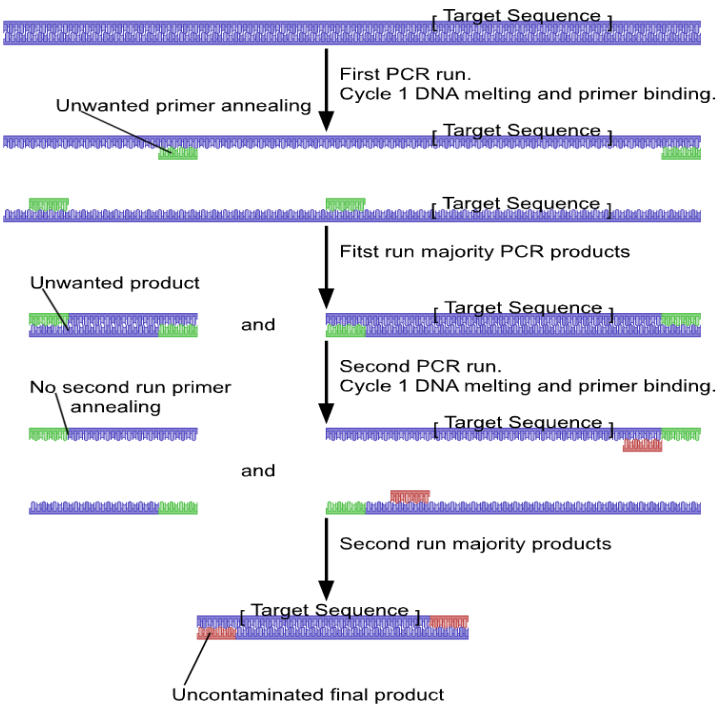

Figure-5: Diagram of PCR Performed on a Strand of DNA. In this diagram, DNA is represented by the purple horizontal line, and primers are shown in green and red. The final amplified product is shown in the lower center of the diagram. By the end of the process, the target DNA sequence is copied billions of times in minutes. (Wheeler, 2005)

The PCR reaction is heated in a computer controlled thermocycler. The initial step at around 94°C denatures the double stranded template DNA to make it single stranded and able to hybridize to the DNA STR primers. Next, the temperature is lowered to about 55°C to allow the DNA primers to anneal to the STR location. Then the temperature is raised to about 72°C the optimum of the Taq polymerase for synthesizing new DNA from the primers. This cycle of denaturation, annealing, and DNA synthesis is repeated about 35-50 times to amplify the STR sequence between the primers. Each time the temperature is increased, the double helix unzips into two strands. Once this happens, the primers attach to the 3' ends of each STR sequence.

The Taq polymerase then connects to the primer and facilitates the synthesis of a new DNA strand. Thus for each cycle, there are two molecules containing the STR sequence. The thermal cycler repeats the cycle many times, the number of replicated STR target sequences increases exponentially as the number of cycles increases. After 30 cycles, there are over 1 billion such molecules. Because PCR-STR analysis is so fast and sensitive, it has become the most popular method used today for DNA analysis.

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Chapter-2: DNA Forensics

Mark Lerret

DNA fingerprinting is a new and expanding field that combines complex aspects of science, law, and ethics. In spite of the power of this technology, none of the evidence is allowed in court if it is collected incorrectly, allowing contamination or degradation. This chapter focuses on the collection of DNA evidence from a crime scene, and how it can be studied and analyzed properly.

A properly collected and analyzed piece of DNA evidence can find a suspect guilty of a crime, or prove he is innocent. In order to play such a critical role in the courtroom, DNA must be collected carefully to prevent contamination and degradation. As was learned in the OJ Simpson case, even a seed of doubt in the jury's mind about the validity of genetic evidence can cause them to reject it. Standards and protocols now are in place to increase the accuracy of the information the DNA surrenders. The chain of custody is the record of the journey that the evidence takes from the crime scene to the courtroom, and is important for documenting who has handled the evidence and why.

How DNA Evidence is Collected

An illegal action turns a simple location into a crime scene, and the clues that are left behind are sometimes the only indications as to what happened. Evidence of all kinds is handled with great care to ensure its integrity, and to ensure that the investigators are able to use it to correctly decipher what happened at the scene. The investigator should know the crime lab's preferences on how the evidence should be packaged and delivered. This changes periodically in a single lab as technology improves, and personnel change. It will also vary from lab to lab.

Multi-Level Crime Scene Containment

The job of controlling the crime scene begins with the first officer on the scene, who is responsible for securing the area where the crime occurred and any evidence that may be there. Usually three levels of containment should be established (**Figure-1**) so that the crime scene investigators can work quickly and efficiently to collect evidence and walk through the crime. The first level of containment (yellow in the diagram) is the most important. It must encompass the immediate crime scene completely with room to spare, so that all possible evidence is within this area. This is the area where crime scene investigation is at its most intense, with officers and investigators looking for evidence, doing walkthroughs of the scene, and taking pictures of evidence that has been discovered. It is very important that only essential personnel are within this barrier, to limit the risk of compromising evidence.

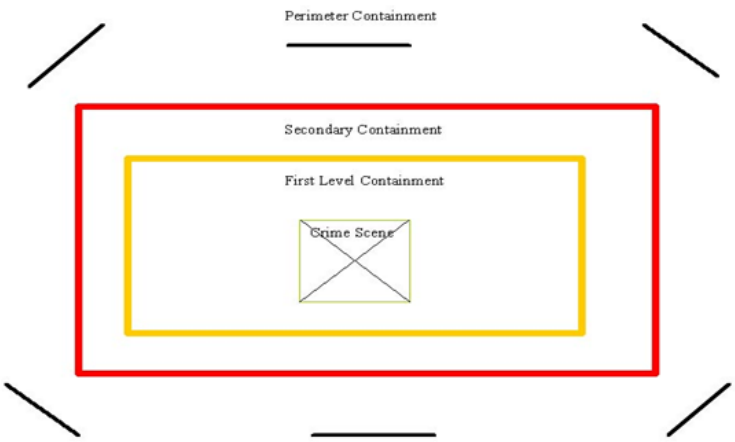

Figure-1: An Example of Three Levels of Containment for a Crime Scene. Photo courtesy of Dagnan, 2006.

The second level of containment (red in the diagram) creates a barrier beyond the first level, creating a buffer zone outside the first level. This extra protection around the crime scene

further protects the evidence from outside tampering. It also creates an area that officers can occupy when they are not doing direct crime scene work. The second level is also a good place for staff meetings that do not need to be within the immediate crime scene. This limits the amount of incidental contamination, and streamlines the crime scene investigation. This is particularly good for DNA evidence, because idle officers in the crime scene area can easily drop genetic material that can contaminate the evidence. Hair and dead skin cells easily fall from the body and both have enough DNA to contaminate the evidence.

The third and final level (black in the diagram) is known as the perimeter containment. It is a third barrier put up to keep onlookers, bystanders and the media outside the first and second levels. While the first two barriers are set up tightly with police tape, the perimeter is loosely set with barricades and police vehicles.

This multi-level containment creates a secure and efficient space to investigate the crime scene. Only investigators handling and observing the evidence are able to get near it. It cannot be tampered with or unintentionally compromised. Multi-level containment enhances the quality of evidence, particularly DNA evidence, found at the scene. It is absolutely vital that DNA is handled, packaged and transported properly, or it will become useless in court (Dagnan, 2006).

Evidence Collection

Common sources of DNA evidence include blood, semen and hair. Biological evidence of this kind must be collected carefully and packaged and stored properly. DNA should be collected by an investigator wearing latex gloves and a surgical mask. Eye covering should be worn when collecting fluid samples. Dry samples should be stored in bags, including stained clothing. With bodily fluids, there is always the risk of diseases being transmitted from the

evidence to the investigators, so any samples that potentially have biohazards should have a note of caution included with it, in agreement with "universal precautions". Universal precaution says that it should be assumed that any biological material is contaminated with pathogens such as HIV or Hepatitis B.

Once the evidence has been collected, all instruments and items that have touched the fluids need to be decontaminated. All instruments should be cleaned well, and contaminated clothing should be disposed of. All samples should be meticulously labeled. If these procedures are followed, the evidence can hopefully be presented to a jury even years later (Byrd, 2000).

Sources of DNA Evidence

Genetic material is being dropped from your body and left behind almost constantly. This is good news for crime scene investigators, because there is a good chance that DNA from a suspect will be left at the scene. However, the amount of DNA left must be enough to study. **Table-I** shows various types of biological samples and their DNA content. Note that semen and blood are especially good sources of DNA.

Table-1: List of How Much DNA is Present in a Biological Sample
(Kaye and Sensabaugh, 2000)

Type of Sample	DNA Content	PCR Success Rate
Liquid Blood	20,000-40,000 ng/mL	>95%
Blood Stain (1 cm x 1 cm)	200 ng	
Liquid Semen	150,000-300,000 ng/mL	>95%
Post-coital Vaginal Swab	0-3,000 ng	
Liquid Saliva	1,000-10,000 ng/mL	50%-70%
Plucked Hair (with root)	1-750 ng	>90%
Shed Hair (with root)	1-12 ng	<20%
Urine	1-20 ng/mL	

Blood can be found at the scene of many different types of crimes, including homicides, sexual assaults, and burglaries. Blood evidence provides important facts about a crime scene. Patterns of blood can indicate a path taken by a moved body, or spatter patterns can indicate whether a wound was self-inflicted. DNA from bloodstains can be used to create a strong link between a suspect and a crime. The importance of blood makes it necessary to document, collect and preserve any evidence of this kind properly. An improperly handled sample can be thrown out in court immediately, while a properly handled sample can be presented to a jury years later.

The advancement of blood stain technology reflects the large rate of improvement in all aspects of molecular biology and genetics. In the early 1970s, labs could only determine the general ABO blood type of a suspect. But the ABO blood type is very far from statistically individualizing, depending on the type it can only narrow the list of suspects from 4 to 49% of the population. But by the 1990s, it was possible to statistically narrow the identity of one person from several millions, and potentially even several billions.

If a large enough amount of blood is present, RFLP testing can be used. This analysis (discussed in detail in Chapter-1) can identify a single person out of a population, giving investigators a powerful method of identification. The other main method of DNA analysis is by PCR. PCR testing requires much less blood, even from a single cell. Depending on how many different locations are analyzed in the sample, it can be as discriminating as the RFLP approach. The 13 core loci currently entered into CODIS raises the chance of an incorrect match to one in billions. A problem with PCR is it is prone to contamination. Studies have shown however that false results due to contamination are unlikely if proper procedures are used, and the only chance of false results is with direct cross contamination with wet samples.

The final DNA analysis does not *definitively* link a suspect to a crime in court, it gives a statistical probability that blood came from the suspect. When performed correctly, DNA testing can say with a very high probability that only one in several million people can have the DNA profile that was found, and that the suspect has that profile.

Valuable blood evidence takes three common forms. The first form is blood from the victim found on the suspect or a possession of the suspects. It can also be the suspect's blood found on the victim or the victim's possessions. Either can link the suspect to the victim convincingly. Third, the evidence can be based on the blood spatter pattern or location at the crime scene. When analyzing blood on clothing, caution must be taken as other individuals may have come in contact with the item (Far, 2011).

Some chemical compounds are able to make bloodstains more visible on a crime scene. One such compound is luminol. Luminol mixes with hemoglobin and creates a new molecule with more energy than the reactants had. This energy is given off as visible light, causing the bloodstain to glow in a blue-green color (**Figure-2**).

Figure-2: A Bootprint Illuminated by Luminol. *Photo courtesy of howstuffworks.com*

Once a crime scene has been sprayed with luminol and the potential blood stains are revealed, they must be documented with photographs or video. Although luminol can be very

useful, it has several drawbacks. The chemicals in luminol can dilute blood to the point that it cannot be tested for genetic markers, effectively destroying it as evidence. Luminol also reacts with many substances, including copper ions and compounds, iron compounds and cobalt ions, as well as bleach and some dyes. If a bleach stain is mistaken for a blood stain, the conclusions of the investigators could be radically different from the way the events in question unfolded. If a blood stain is not visible or detectable without luminol, it is very likely that there is not enough blood to be of any use to a crime lab. For these reasons, luminol should be a last resort at a crime scene, and should not be used before other methods are performed (Howstuffworks, 2011).

Besides blood, other common sources of DNA evidence include semen, hair, and saliva. Creative investigating can lead to unusual sources of evidence. **Table-2** lists various kinds of crime scene evidence that are likely to contain DNA. For example, saliva can be found on postage stamps, cigarette butts, and the rims of cups and glasses. In one rape case, a masked perpetrator forced the victim to perform oral sex on him. When he was apprehended, the victim's DNA profile matched that of DNA swabbed from his penis. In the same case, a single hair was found in the victim's throat, whose DNA profile matched the suspect. Investigators must be prepared to search in unusual places for evidence to solve crimes more accurately and efficiently.

Table-2: List of Possible DNA Evidence Sources at a Crime Scene *(dna.gov)*

Evidence	Possible Location of DNA on the Evidence	Source of DNA
baseball bat or similar weapon	handle, end	sweat, skin, blood, tissue
hat, bandana 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 are	blood, sweat, semen

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

Chain of Custody, Contamination and Degradation

Once DNA evidence is collected, the evidence must be bagged and labeled. From that point on, individuals who have possession of the evidence must be documented strictly. This protocol is known as the “chain of custody”, and it establishes that the evidence was continuously in the possession of law enforcement officials, and was not tampered with. In general, the fewer people who handle the DNA the better, as a shorter chain of custody lowers the chance of contamination and shortens the list to be read in court. Additionally, if the DNA is contaminated, it may be necessary to know who handled the evidence, so their profiles can be compared to those found on the evidence. Although the chain of custody is necessary for many other types of evidence, it is vital to DNA evidence because of the sensitivity of the analysis (Law Library, 2011).

Contamination occurs when a DNA sample is mixed with DNA from a different source.

This is a significant problem in DNA handling, because DNA is microscopic and can be shed and left behind by any person and many other organisms. Contamination usually renders the sample useless in court. DNA labs enforce strict protocols to limit the effect of contamination on samples. The proper way to handle DNA from a crime scene is to be very careful not to touch it with anything that could have DNA from another source on it. The evidence should be dried thoroughly, packaged and labeled clearly. Once in the lab, it should again be handled only with gloved hands and sterile instruments, ensuring that only the crime scene DNA is present and analyzed. To be most careful, gloves should be changed frequently, and disposable tools should be used if possible. PCR presents several potential sources of contamination beyond genetic material in the environment. During the preparation steps, DNA can be mixed with other material from an apparatus such as a micropipettor that has not been cleaned properly. Once contamination has occurred, it is usually impossible to know how or when it occurred. Even with the most stringent procedures, the most careful staff and the most sterile instruments, contamination cannot be eliminated, so it is important to prepare multiple DNA samples from different sources if possible. Although contamination remains a possibility, the chances can be minimized if the DNA is handled correctly (*Understanding DNA Evidence, 2001).*

In addition to the possibility of contamination, DNA is prone to degradation, or the breakdown of the molecule over time. Many factors affect how quickly DNA breaks down. Heat and humidity both cause DNA to fall apart faster. Even sunlight can break it apart. The longer DNA remains at a crime scene, the longer it is vulnerable to degradation from these sources. As the molecule breaks down randomly, it is possible for the STR regions (discussed in chapter 1) to break. The larger the STR region, the more likely it is to fracture. If this is the case, these strands cannot be amplified or studied. DNA can also be damaged by careless

handling by investigators and officers, for example if they store a dried DNA sample in a plastic bag that traps moisture. Once damaged, the DNA cannot be fixed, and it usually will not be useful as evidence. Degraded DNA will show a different graph after electrophoresis than well maintained DNA. Some bands will be so faded that they cannot be identified, while other bands may not appear at all because of heavy damage (The National Forensic Science Technology Center, 2011).

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Chapter-3: Landmark DNA Court Cases

Brendan Stitt

With the passing of the Fifth Amendment in 1791 and the Fourteenth Amendment in 1868, due process was established and written into the highest law of the land, the Constitution. The burden of proof that the prosecution is required to meet and the presumption of innocence given to each defendant are based on these due process clauses. As such, complex technical evidence has been a key factor in legal proceedings for a long time. For each advance in the field of forensic science, there must be a subsequent process decided on by the legal system as to how the new technology may be utilized in the courts. As the acceptance of the new advance increases among the scientific community, and as standards of practice are established, the likelihood of the admissibility of the new technology in court cases will also increase. One of the most used of the new complex technologies is DNA fingerprinting. The purpose of this chapter is to discuss several key landmark court cases that established legal precedence for accepting DNA fingerprinting into U.S. courts.

The application of DNA technology to forensic science was initiated in 1985 when Sir Alec J. Jeffreys of Leicester University in England discovered a method for identifying individuals based on DNA, which he called "DNA Fingerprinting" (Jeffreys, Wilson, & Thein, 1985). DNA Fingerprinting is a misnomer of sorts as it does not analyze fingerprints, but rather refers to the methods used to identify a person based solely on their DNA. As discussed in previous chapters, samples taken from crime scenes usually include blood, saliva, semen, or other bodily fluids. The DNA is extracted from the sample, analyzed, and compared to a sample

provided by the suspect(s) or individual(s) in question. A match between two samples indicates that the individual was present at the crime scene and can subsequently be used to help establish or disprove guilt.

Since 1985, DNA fingerprinting has been named “the single greatest advance in the 'search for truth' ... since the advent of cross-examination” (People v. Wesley, 1988); indeed it was widely hailed as infallible and a decisive tool in the prosecution process, being called also “the greatest single breakthrough in the fight against crime since fingerprints themselves were discovered in 1901” (DNA Testing on the Increase, 1987). However, that is not to say that DNA fingerprinting has not also been criticized, refuted, deemed prejudicial, and claimed to be in violation of the Fourth Amendment.

While popular culture would lead the public to believe that DNA evidence is readily available and admissible in court, this is often not true. DNA fingerprinting may be widely accepted now, but it was not always so. The standards for accepting complex technical evidence in court cases have continued to change and adapt through the years to ensure accuracy and reliability. If DNA samples are not collected or analyzed using methods to prevent contamination or degradation, cross-contamination may render the results inadmissible or create false positives in reporting that could allow a guilty individual to go free or an innocent individual to be wrongfully punished. Any allowance of this would go against the foundations of law: the coercive power of the court, the objectivity given to competing claims, and the objectivity of the meting out of justice should it be deemed necessary (Luban, 2001). The court cases involving the relevance and admissibility of DNA and other complex technical evidence are numerous. As such, this chapter shall examine six key cases that best established a precedent as to how DNA fingerprinting and other complex technical evidence are admitted in U.S. courts.

Frye v. United States, 1923

On July 17, 1922 in a Washington, D.C. court, the trial that would lead to the establishment of the *Frye Rule* began. James Alphonzo Frye was accused of murder of a wealthy black physician. His lawyer, Richard V. Mattingly, being unsuccessful at finding witnesses to corroborate Frye's alibi, had turned to William Marston (who went on to create Wonder Woman and her Lasso of Truth) and his systolic blood pressure test, a primitive "lie detector". Marston took Frye's blood pressure using a standard medical blood pressure cuff and a stethoscope after asking him several questions (Marston, 1938). Marston was convinced of Frye's innocence after administering his test and wrote: "No one could have been more surprised than myself to find that Frye's final story of innocence was entirely truthful! His confession to the Brown Murder was a lie from start to finish (Marston, 1938)."

Mattingly attempted to place Marston on the stand as an expert witness to validate the findings of his systolic blood-pressure testing, but the judge would not allow it, nor would he allow Marston to hold a demonstration of the test in the court room. With the absence of witnesses to support his alibi and Marston's tests rendered unusable, Frye's defense crumbled. He was subsequently found guilty of murder in the second degree and sentenced to life in prison (Starr, 1983).

Mattingly appealed Frye's decision based on the grounds that the trial court had erred when it refused to introduce the results of the systolic blood pressure test and Marston's expert testimony into evidence. On December 3, 1923, in the Washington, D.C. Circuit Court of Appeals, the decision on Frye's appeal was delivered by Judge Josiah A. Van Orsdel and other two circuit court appeal judges. The judges upheld the earlier trial court's decision to not allow the lie detector test or Marston's testimony into evidence as the test was at the time not widely

accepted in the scientific community. In the opinion written by Van Orsdel, the *Frye Rule* was established: "Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field to which it belongs (Frye v. U.S, 1923)."

Orsdel's opinion set the standard for many years to come, making the admission of lie detector tests virtually impossible until they gained some popularity in the 1970s and 1980s, however most U.S. judges to this date do not believe this test is reliable and do not allow its results in court as conclusive evidence. The *Frye Rule* set a longstanding precedent and was the deciding factor in the admission of expert testimony and technical evidence for 52 years until the establishment of the more lenient Federal Rules of Evidence 702 was established in 1975.

Federal Rules of Evidence 702, 1975

The passing of the *Rules Enabling Act* by Congress granted the Supreme Court the authority to promulgate procedural rules for federal courts (1934). The Act gave the Supreme Court the responsibility of proposing standards of practice and procedure for the courts. Not much was done until 1965 when Chief Justice Earl Warren appointed a 15-member Advisory Committee to draft an all-inclusive code of evidence (Wright & Kenneth, 1977). The drafting process continued with numerous revisions until February 5, 1973, when the Advisory Committee submitted the proposed rules to Congress (Wright & Kenneth). On March 30, 1973,

Congress passed a bill to delay the enactment of the proposed rules (Public Law 93-12, 1973), with the delay being blamed on the Watergate affairs occurring simultaneously. After almost two years of hearings by the House and Senate, the president finally signed the *Federal Rules of Evidence* into law on January 2, 1975 (Pub. L. No. 93-595). More than fifty years after the Frye Standard was established, the Federal Rules of Evidence 702 was promulgated. In its most recent amendment, *Rule 702* states that:

> "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case (2000)."

Many judges, legal scholars and litigants were in debate as to whether the rule superseded the Frye Rule or was being applied to it. However, Rule 702 was quickly adopted as the measuring factor for the allowance of complex technical evidence or expert testimony over the Frye Rule due to its more lenient guidelines which provided a standard practice for the allowance of evidence and testimony that depended upon reliability and relevance rather than general acceptance. The *Federal Rules of Evidence 702* was used as the deciding factor in the admissibility (or inadmissibility) of evidence in several landmark court cases, most notably in *Downing v. United States* (1985), *Andrews v. Florida* (1988), *Two Bulls v. United States* (1990), and *Daubert v. Merrel Dow Pharmaceuticals* (1993).

Downing v. United States, 1985

From 1978 to 1979, a group of individuals operating under the name of the Universal League of Clergy (U.L.C) developed a plot to scam several vendors of their goods. The members of the group operated under names such as "Malcolm Sloane", "Reverend Olson", and the mastermind of the operation, "Reverend Claymore". The Attorney General contended that John W. Downing was the mysterious "Reverend Claymore" and he was indicted for mail fraud, wire fraud, and interstate transportation of stolen property. Downing, along with his co-defendants, James A. Silva and Richard Piazza, claimed that they were simply the puppets of Claymore and that none of them was, nor knew the identity of, the "Reverend". The prosecution's case was built almost entirely upon the testimony of twelve eyewitnesses who claimed that Downing was Claymore based on observations between 5 and 45 minutes in length. The defense sought to discredit the testimony of these eyewitnesses, calling upon cognitive psychologist Dr. Robert Weisburg to provide expert testimony on the unreliability of eyewitness testimony. The district court refused to admit the testimony, stating that it did not meet the helpfulness requirement of *Federal Rules of Evidence 702*. So the eyewitness testimony was allowed, and Downing was found guilty of mail fraud and wire fraud (United States v. John W. Downing, 1985).

Downing appealed on the grounds that the eyewitness testimony was unreliable and that the ruling could have differed had the expert testimony been deemed admissible. In 1985, The United States Circuit Court, Third Circuit, Judge Becker residing, ruled that the district court had erred, and that the admissibility of expert testimony is not automatic but conditional. The district court was to hold an evidentiary hearing, a pre-trial hearing in which the relevancy of the expert testimony would be considered. Should the testimony be deemed sufficient, then a re-trial would be granted. Upon conclusion of the pre-trial inquiry, the district court reinstated the original

guilty verdict as they found that: (1) Dr. Weisburg's testimony was not significantly reliable to assist the jury in making an accurate decision; (2) the evidence would confuse, overwhelm, or mislead the jury; and (3) the eyewitness testimony was of sufficient frequency and duration to void the negative expert testimony (United States v. John W. Downing, 1985).

This threshold inquiry was developed based on the helpfulness standard of *Federal Rules of Evidence 702* and was based on two factors: "(1) the reliability of the scientific principles upon which the expert testimony rests, hence the potential of the testimony to aid the jury in reaching an accurate resolution of a disputed issue; and (2) the likelihood that introduction of the testimony may in some way overwhelm or mislead the jury (United States v. John W. Downing, 1985)." This threshold inquiry became the standard for determining the admissibility of evidence under *Federal Rules of Evidence 702*, and based this admission of relevance, makes it more liberal than the general acceptance requirement of the *Frye Standard*. This pre-trial hearing superseded the Frye standard for admissibility, setting the new precedence for cases such as *Andrews v. Florida*.

Andrews v. Florida, 1988

The case of *Tommie Lee Andrews v. State of Florida* marked the first trial in which DNA evidence was admitted in U.S. courts. A Florida woman's house was broken into on the night of February 21, 1987 and she was raped at knife point and then burglarized. A similar string of over twenty criminal acts occurred over the next six months. The police believed that the acts were being committed by the same individual. On examination of a screen from one of the victim's windows found on the ground, two fingerprints were lifted. These fingerprints matched the right

index and middle finger of Tommie Lee Andrews, who had been arrested for prowling a woman's yard in the early morning hours in the same area where the nearly two-dozen assaults had occurred.

The frequency and similarity of the attacks led law enforcement to believe that there was a serial rapist in the neighborhood. The perpetrator had several oddities that were his signature. He would flick the lights on and off several times during the attack and examine the victim's driver's license before leaving (Lewis, 1988). The perpetrator also exhibited care in removing any evidence left behind and had knowledge of the victim's schedules, indicating long periods of observation prior to committing the assault. Based on this character profile, the police set up patrols in the neighborhood and their efforts paid off when Andrews was arrested on March 1, 1987 after a woman called to report that a man was lurking in her yard (Aronson, 2007).

The prosecution knew that the case would be difficult based solely on the testimony of the first victim, the fingerprints, and the forensic blood group analysis, which showed that the person responsible for the first assault was a member of 65% of the male population (Andrews v. State, 1988). While reading a magazine for lawyers, Jeffrey L. Ashton, an assistant state prosecutor for Florida, saw an ad by Lifecodes Corporation about DNA paternity testing. Ashton was curious whether the procedure for paternity testing was the same that was used in England in the case of Colin Pitchfork, the first criminal convicted of murder based on DNA fingerprinting evidence (Wambaugh, 1989). Ashton contacted Lifecodes and learned that it was indeed the same test. With this information in hand he approached Tim Berry, chief prosecutor on the Andrews case. They submitted six samples of Andrews' DNA and two came back as positive matches to the semen collected from the first two victims (Dersken, 2003).

This was the first time in the United States that such a test had been conducted and submitted as as evidence in a criminal conviction. Although the Frye rule was still the generally accepted standard for admissibility, the Florida courts were in much debate as to how to admit scientific evidence. The opinion from the appeals hearing for Andrews states "We begin by confessing some uncertainty as to the standard applicable in this state governing admissibility into evidence of a new scientific technique" (Andrews v. State, 1988). According to the Florida Evidence Code, "if scientific, technical or other specialized knowledge will assist the trier of fact in understanding the evidence or in determining a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training or education may testify about it in the form of an opinion; however, the opinion is admissible only if it can be applied to evidence at trial (Florida Evidence Code)." The prosecution was therefore not required to meet the general acceptance requirements of the Frye standard, but rather the relevancy test of *Downing v. United States* and the reliability test of *Federal Rules of Evidence 702*.

At the pre-trial hearing, the volume of literary citations of DNA fingerprinting, its use in medical applications, the widespread study of molecular biology focusing on DNA, and the knowledge that the methodology used by Lifecodes in their testing had been used for almost ten years convinced the judge to allow the DNA evidence. On the stand, Dr. Michael Baird, the manager of forensic testing at Lifecodes, stated that the probability of the DNA match coming from someone other than Andrews was one in ten billion. The defense knew that they would now be hard pressed to convince the jury of Andrews' innocence with the DNA evidence matching him to two of the rapes. Hal Uhrig, the defense attorney, could not find any expert witnesses to confess against the prosecution's expert testimony of Dr. David Housman. Uhrig stated that Housman was like "an angel" among the scientific community and that any experts he contacted

stated something akin to "if Housman has examined the evidence and he says that it's good, then it's good (Aronson, 2007)." When Berry asked Baird to explain the statistics behind the DNA evidence, Uhrig objected on the grounds that that type of testimony was inadmissible. The judge ruled that the statistical evidence could not be used in the jury's decision as there was no legal justification given for the admission of the statistical evidence. The result was a hung jury, noting that the testimony of the first victim without further validation could not be readily trusted due to a lapse in time affecting her memory and the general lack of knowledge on DNA fingerprinting as a new technology contributed to this result.

At the retrial, the statistical evidence was deemed admissible under the reliability test of *Federal Rules of Evidence 702* and the relevancy test of *Downing*. The reintroduction of the DNA evidence, together with the fingerprint matches and the testimony of the first victim, combined with the identification of Andrews in a photo lineup from the most recent victim, solidified the case for the prosecution. After two and a half hours of deliberation, the jury returned with a guilty verdict. Andrews was sentenced to 22 years for being guilty of burglary, sexual battery and aggravated battery, although this sentence was later increased to a 115-year sentence when his DNA was found to match DNA samples collected from several other victims in the area. Andrews' attempt to appeal the case was overturned with the 5th District Court's opinion:

> "The trial court did not abuse its discretion in ruling the test results admissible in this case. In contrast to evidence derived from hypnosis, truth serum and polygraph, evidence derived from DNA print identification appears based on proven scientific principles. Indeed, there was testimony that such evidence has been used to exonerate those suspected of criminal activity. Given the evidence in this case that the test was administered in conformity with accepted scientific procedures so as to ensure to the greatest degree possible a reliable result, appellant has failed to show error on this point (Andrews v. State, 1988)."

The decision to admit DNA evidence in the trial began the mindset that DNA is "infallible" evidence, as is the popular opinion today. As stated in *Downing*, the relevancy test required the court to look to other factors in determining the admissibility of the DNA evidence as it had not established a "track record". The conviction of a felon in a violent sex crime using DNA evidence also led to the establishment of DNA databases in the states to assist in the conviction of repeat offenders or violent criminals. The *Andrews* case set the precedence for the admission of DNA evidence in U. S. courts and became especially important in cases involving rape other violent crimes where eyewitness testimony alone could be deemed unreliable.

Two Bulls v. United States, 1990

In South Dakota, in 1989, Matthew Sylvester Two Bulls was arrested and charged with aggravated sexual abuse and sexual abuse of a minor. A fourteen-year-old girl had been raped on the Pine Ridge Indian Reservation. The girl's underwear was collected by the police and DNA analysis was performed on the semen found on the underwear. The FBI crime laboratory concluded that the DNA collected from the semen was a match to the blood taken from Two Bulls (the probability of someone other than Two Bulls providing the match was one in 177,000). Two Bulls challenged the acceptability of that evidence and motioned for a suppression hearing. At the pre-trial hearing, the district court judge decided that the DNA evidence would be admitted after hearing the testimony of only the government's first witness, based on the grounds that general acceptability of DNA evidence by the scientific community had been established (United States v. Matthew Sylvester Two Bulls, 1990).

Two Bulls appealed, arguing that the court should have used the more stringent *Frye test* rather than *Federal Rule of Evidence 702* in the determination of whether the DNA evidence should be admitted and that the district court had violated his due process by not completing the pre-trial hearing. The justices hearing the appeal were wary of how to proceed. DNA fingerprinting was still a fairly new and disputed technology among both the scientific community and the legal system. The opinion from the trial cites some of the difficulties of DNA profiling including: a sample too small for DNA typing, a sample rendered incapable of testing due to contamination or degradation, interpretation of DNA test results, and the small number of laboratories conducting the tests (United States v. Matthew Sylvester Two Bulls, 1990). The precedence had been set for admission in several state courts prior to this trial however, such as in *Andrews v. Florida* and *People v. Castro* (in which a three-prong test was used to determine the admissibility). The cases were varied in their deciding factors however. While many relied on the *Frye test* (*Cobey v. State*, *People v. Wesley*, *Glover v. State*), more relied upon the *Federal Rules of Evidence* and a relevancy or reliability test. An assessment conducted by the United States Congressional Office of Technologies supported the validity of DNA testing and concluded that the testing could be applied to forensics, so long as it was conducted in a proper manner by skilled professionals (1990).

Two Bulls declared that a three-prong test like the one used in *Castro* should be used in determining the admissibility, not solely a test of relevancy and reliability. The three prongs of the *Castro* case were: (1) general acceptance from the scientific community on the theory of reliable results from DNA testing; (2) general acceptance from the scientific community as to the procedures used in DNA testing which can produce reliable results; and (3) whether the

laboratory's procedures matched those generally accepted by the scientific community. The court in the *Castro* case concluded that:

"…given the complexity of the DNA multi-system identification tests and the powerful impact that they may have on a jury, passing muster under Frye alone is insufficient to place this type of evidence before a jury without a preliminary, critical examination of the actual testing procedures performed in a particular case (People v. Castro, 1989)." The government argued that the Castro test was too stringent and the *Federal Rule of Evidence 702* was a more liberal test of admissibility that superseded the Frye standard and contradicted the Castro test.

The court hearing Two Bulls' appeal gave the opinion that both the *Frye standard* and *Federal Rule of Evidence 702* required "the same general approach to the admissibility of new scientific evidence (United States v. Matthew Sylvester Two Bulls, 1990)." The court went on to conclude that while DNA evidence may seem to be generally accepted, it should not be admitted as evidence unless a pre-trial hearing is conducted which hears testimony from both sides and examines the procedures used by the laboratory conducting the analyses. Two Bulls' conviction was overturned and the case was remanded to trial court, with an expanded pre-trial hearing to be conducted. The justices concluded their opinion by establishing a new five-prong test which set a new precedence for the standard in determining admissibility of DNA evidence. The five decisions that had to be determined in the pre-trial hearing were as follows: "(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 Rule 403 (United States v. Matthew Sylvester Two Bulls, 1990)."

Thus, although DNA testing and the use of DNA evidence was seen as generally accepted just five years after its inception, there was still much debate as to the merit of DNA fingerprinting and questions on standards for testing. Sharing the opinion of the *Castro* case, a caveat was placed on acceptance of DNA evidence without proper examination into how it was obtained. After the new Two Bulls pre-trial hearing was conducted, the court upheld the admissibility of the DNA evidence, and Two Bulls' original conviction of aggravated sexual abuse and sexual abuse of a minor were upheld.

***Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 1993**

The case that would establish the *Daubert standard* began in 1989, when Jason Daubert and Eric Schuller, minor children, alleged that their serious birth defects had been caused by their mothers' ingestion of an anti-nausea drug called Bendectin, manufactured by Merrell Dow Pharmaceuticals, Inc. They initially filed the suit in the California state courts, but the trial was moved to a Federal District Court on diversity grounds (William DAUBERT, et ux., etc., et al. v. MERRELL DOW PHARMACEUTICALS, INC., 1993). Merrell Dow moved for a summary judgment, as they claimed that Bendectin did not cause human birth defects and that the petitioners would be fully incapable of overcoming any burden of proof stating otherwise. The pharmaceutical company bolstered this contention with an affidavit submitted by Dr. Steven Lamm which stated that a review of over 30 publications had found Bendectin to be a teratogen in humans. The evidence of the eight experts brought forth by the petitioners to combat this

affidavit was deemed insufficient as that testimony was based on the effects of Bendectin in lab animals, and the reanalysis of studies was conducted without peer review or publication. As such, the district court awarded the summary judgment to Merrell Dow.

The petitioners appealed the case, but the Ninth Circuit Court of Appeals upheld the summary judgment on the grounds of the *Frye standard*. Judge Kozinski wrote in his brief opinion that "such evidence creates a substantial danger of undue prejudice or of confusing the issues or… of misleading the jury (Daubert v. Merrell Dow Pharmaceuticals, Inc., 1991)," using this as his argument for why the *Frye standard* was properly applied as the deciding factor in not admitting the evidence brought forth by the petitioners.

Losing yet again, the petitioners petitioned for a *writ of certiorari* and were granted it on the grounds that there were "sharp divisions among the courts regarding the proper standard for the admission of expert testimony (William DAUBERT, et ux., etc., et al. v. MERRELL DOW PHARMACEUTICALS, INC., 1993). The Supreme Court vacated the opinion of the lower appeals court and remanded the case on the grounds that *Federal Rule of Evidence 702* superseded the Frye standard. In his opinion, Justice Blackmun wrote that the *Frye standard* went against the "liberal thrust" of the rules. The court then established a new standard for admissibility, to become known as the *Daubert standard* which expanded the examination from relevancy to examinations of reliability, through the use of peer review, publications, statistical error data, etc. The Supreme Court also established four factors for the trial courts to use as guidelines in judging the admissibility of expert testimony or complex technical evidence. The factors paralleled those established in *Downing* and other earlier cases and are as follows:

- Whether the expert's technique or theory can be and has been tested

- Whether the technique or theory has been subjected to peer review and publication
- Whether the technique or theory has an acceptable known or potential rate of error and the existence and maintenance of standards controlling the technique's operation
- Whether the technique or theory has general acceptance

The Supreme Court also held that judges have a "gatekeeper" role, with the responsibility to "ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable (William DAUBERT, et ux., etc., et al. v. MERRELL DOW PHARMACEUTICALS, INC., 1993)." This new *Daubert standard* was applied to almost all DNA cases following its establishment. However, since the Supreme Court decision was statutory rather than constitutionally based, the standard was not federal law, allowing states to decide how evidence would be accepted into their courts. In 1995, almost half of the state courts were still using the *Frye standard* (Meaney, 1995).

Upon being remanded, the evidence brought forth by the petitioners was still deemed inadmissible under the new standard, though not without some reluctance on the part of the court in terms of accepting their new role. Chief Justice of the Supreme Court, William Rehnquist, wrote an opinion that both concurred and dissented with the opinion of Blackmun, agreeing that the Federal Rules should supersede the Frye standard, but that the four Daubert factors were still "vague and abstract" and wondered at the ability of judges to serve as "amateur judges" in their new role (William DAUBERT, et ux., etc., et al. v. MERRELL DOW PHARMACEUTICALS, INC., 1993).

Chapter-3 Conclusions

As the collection of DNA evidence and the tests conducted on it become more advanced, so too have the efforts of opposing parties to refute the evidence, call it unreliable, or bring in their own forensic experts as a counter. With shows like *CSI: Crime Scene Investigation*, *NCIS*, and *Bones* becoming popular among the mainstream public, this helps the public to have a better understanding of DNA, but with its portrayal on these shows, it is often seen as almost infallible. As such, the concerns that were raised years ago as to the helpful nature of DNA evidence without misleading the jury still stand today.

Statutes of limitation have been extended due to the introduction of DNA evidence, whether used to exonerate an innocent individual or bring a guilty person to justice. This is especially relevant in cases of homicide or rape, where victims and witnesses may be too afraid to testify or where the crimes have been committed by a repeat offender. The ability to bring forth DNA evidence in cases such as these better enables the criminal justice system to remove violent perpetrators from the street and establish databases to expedite criminal proceedings in the future.

While DNA evidence quickly grew as one of the most powerful tools ever utilized in court proceedings, criminal or otherwise, the argument for whether it should be admitted has been long fought and still faces obstacles today. As the field of forensic science expands and makes further advances in DNA fingerprinting technology, so too must the courts be ready to adapt their standards of admissibility. Judges must prepare themselves for their roles as "gatekeepers", utilizing the precedence set in cases such as *Two Bulls* and *Daubert* and looking as far to the past as *Frye* to accurately decide whether DNA evidence may be admitted in each

trial, bearing in mind that it must be relevant and reliable without creating confusion, undue prejudice, or misleading the jury.

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Chapter-4: Sensational DNA Cases

Brendan Stitt

As discussed in the previous chapter, the road that led to DNA admissibility in court cases had many speed bumps. But as each of these obstacles was surmounted, DNA quickly became a key factor in solving cases, helping exonerate the innocent and linking suspects to the crime scene or the victims. However, the public perception of DNA in court cases does not necessarily stem from landmark court cases, but from sensational cases. And their perception has also drastically changed. In the earliest cases, the public was skeptical and had little knowledge of the applications of DNA fingerprinting in forensic science. Expert witnesses were relied on to provide this information to the lay jurors. Over the past decade or so, with the influx of forensic science on television shows such as *CSI: Crime Scene Investigation*, *Bones*, *NCIS*, and *Forensic Files*, many believe that the public has garnered an exaggerated view of forensic evidence, as portrayed on these crime shows. The term "*CSI* effect" or "*CSI* syndrome" has been coined to describe the thinking that due to these shows, the burden of proof has increased for prosecutors because the jurors expect forensic evidence similar to that gathered in the fictional instances on television (Lawson, 2009). A 2008 study published in *Criminal Justice Policy Review* claimed that 80 percent of all professionals in the legal field in America believed that they had been in situations influenced by the *CSI* effect (Robbers, 2008).

It is not the precedent-setting cases, the *Two Bulls*, *Daubert*, and *Downing* trials, which stick in the public's mind. The names Jeffreys, Watson, and Crick most likely do not ring any bells to the general public. The court of public opinion looks for those cases that mirror what is portrayed on television – full of drama and exceptional enough to hold attention. The truth is that

cases handled by forensic scientists generally fall short of being spectacular, and those cases do not divert the public or capture their thoughts.

This chapter will therefore examine three of those rare cases, the sensational cases that have the public talking about them years later. Each of the cases will involve DNA evidence; whether as a means of exonerating the arrested, brought forth as evidence but unable to overcome reasonable doubt, or instead used to place the guilty at the crime scene to help prove the guilty are sentenced.

Dr. Sam Sheppard – The Fugitive

July 3rd, 1954, Bay Village, Ohio. The day had the kind of hot and sunny mid-summer weather perfect for boating, swimming, or enjoying the new sport of water skiing on Lake Erie. The holiday celebrating the nation's independence was just around the corner and the quiet Cleveland suburb was looking to have great weather for the celebration as well (Weather Underground, Inc., 2011).

Dr. Sam Sheppard, a well-known osteopathic physician, and his wife Marilyn were enjoying the company of their friends Don and Nancy Ahern. The couples were watching television and Sam was getting sleepy, perhaps a combination of the gentle night breeze and a hard day's work in the emergency room. He politely retired to a daybed in the living room and fell asleep. His seven-year-old son Sam, known by the moniker "Chip", slept peacefully upstairs. Don and Nancy left the house around midnight, and Marilyn went up to bed, letting Sam doze on downstairs (Linder, The Dr. Sam Sheppard Trial, 2006).

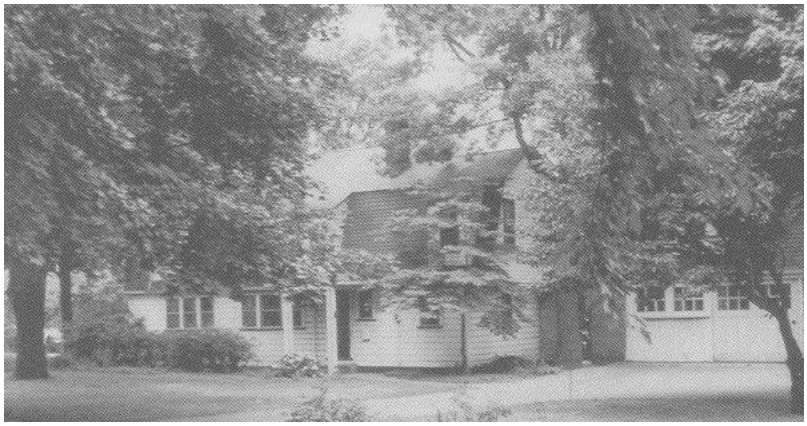

Figure-2. The Sheppard's Home (Linder, The Dr. Sam Sheppard Trial, 2006)

The quiet Cleveland suburb slept peacefully, unaware of the nightmare that was about to befall the Sheppard family in something straight out of a television show or movie. In fact, it is widely believed that the events of that quiet mid-summer night were the inspiration for the television series *The Fugitive*, which ran on ABC from 1963 – 1967 and was later adapted into a movie in 1993 with Harrison Ford in the titular role, although Roy Huggins, the creator of the show, denies this (Cooper & Sheppard, 1995).

Spencer Houk, the mayor of Bay Village received a call at 5:40 a.m. on July 4th. It was a call from his friend Sam Sheppard who frantically exclaimed, "My God, Spence, get over here quick. I think they have killed Marilyn." When they arrived at the Sheppard home a short while later, Spencer Houk and his wife Esther were confronted by Sam sitting down in the den, shirtless and holding his neck (Linder, The Dr. Sam Sheppard Trial, 2006).

Sheppard dazedly related his account of what had happened to the police around 6:00 a.m. At some point during the night, he awoke to the sounds of his wife screaming. He raced up the stairs to find, "a form with a light garment, I believe, at the same time grappling with something or someone (McGungale, 2004)." He attempted to subdue the intruder, but was knocked unconsciousness in the struggle. He came to on the floor of the bedroom and saw his

wife's form, smeared with blood, lying motionless on the bed. A quick check of her pulse revealed that she had none. A noise from outside the house caught his attention and he ran downstairs to find "a form progressing rapidly toward the lake (McGungale, 2004)." He chased down the "bushy-haired" intruder and fought with him again, only to be twisted or choked into unconsciousness again. When he again came to, he was shirtless and in Lake Erie and his watch had also mysteriously gone missing. Sam reasoned that his recollection of the exact events and details, including the sex and number of intruders was foggy due to being knocked unconscious.

The police arrived to find Marilyn's body lying face up on the bed (**Figure-2**). Her face had been severely bludgeoned, her pajama top lifted up over her breasts, and one leg of her pajama bottoms pulled off. Blood soaked the sheets underneath her and was spattered across the walls and closet doors. The autopsy placed her time of death at "about 4:30 a.m." and revealed what only few of the Sheppard's closest friends had known – Marilyn had been four-months pregnant.

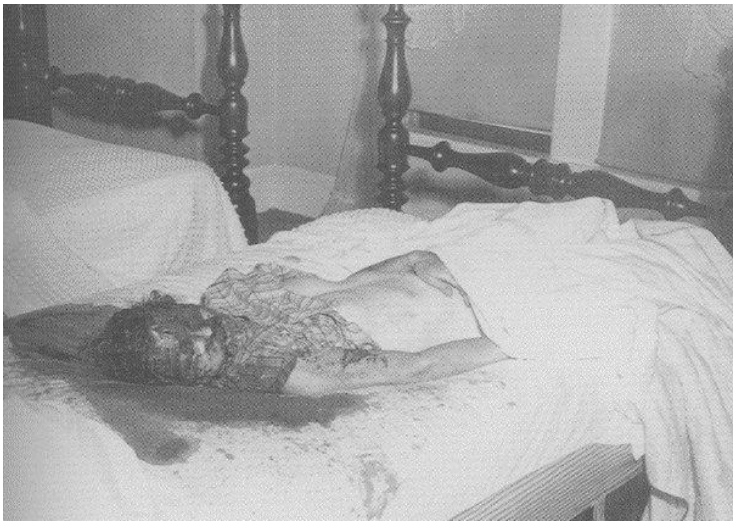

Figure-3. The body of Marilyn Sheppard (Linder, The Dr. Sam Sheppard Trial, 2006)

The police were almost immediately suspicious of Sheppard's vague and somewhat outlandish account. The doctor's bag had been rifled through and other evidence pointing to burglary existed, but it wasn't quite right. If the house had been burglarized, it was by an incredibly tidy thief. The drawers had been pulled open and gone through, but had not been emptied, as is the case in most burglaries (McClish, 2002). There were no viable signs of a break in, and no fingerprints could be found at the scene, though the crime scene was far from secure. The Sheppard's dog was never heard barking, and Sam Jr. had slept through it all.

All three of the local Cleveland papers ran stories about the murder that holiday. The *Cleveland Press* read, "DOCTOR'S WIFE MURDERED IN BAY; Drug Thieves Suspected in Bludgeoning." The *Plain Dealer* ran the banner, "BAY DOCTOR'S WIFE IS MURDERED; Beaten, He Tells of Fight With Intruder." The stories told of a happy family, one headline reading "They Shared Duties, Pleasures of Life (McGungale, 2004)." The reports quickly changed though.

"TESTIFY NOW IN DEATH, BAY DOCTOR IS ORDERED" read the article in the *Cleveland Press* on July 8th (1954). The doctor had been served with a subpoena to appear in the county prosecutor's office by Coroner Samuel R. Gerber, who quickly became a character of media spotlight in the case. The Assistant County Prosecutor, John J. Mahon, "sharply criticized the refusal of relatives to permit the immediate questioning of…Sheppard (NEW SEARCH IS ORDERED FOR CLUES, 1954)" and further declared, "In my 23 years of criminal prosecution, I have never seen such flagrant stalling (McGungale, 2004)." Sam had been in the Bay View Hospital, being treated by his brother for his injuries incurred during the early morning hours of the 4th. Sheppard related the same peculiar tale at each of the police's inquests and could only answer their questions as to where the shirt he had worn was, how Chip had slept through the

whole affair, why the dog had never barked, and details about the bushy-haired intruder with, "I don't know." His refusal to submit to a lie detector test twice was reported on the front pages of both the *Cleveland Press* and the *Cleveland News*. The protection of his family and their defense attorney, William Corrigan, was looked upon with disdain by the locals. In a few short days, the "shared…pleasures of life" that had been described early on quickly turned to talk of Sheppard's supposed affair with a nurse at the hospital where he worked.

Finally, on July 26th, an inquest was held by Coroner Gerber. At the inquest, Corrigan was thrown out by Gerber after Corrigan attempted to get material inserted on the record and the two came to words. The expulsion was met by cheers and applause by the almost 200 in the audience for the inquest. The headlines of that afternoon were all but the nail in the coffin of Sam's guilt in the public's eye. "DOCTOR LIES, SUSAN CHARGES; TELLS OF GIFTS, MARRIAGE TALK" the *Press* proclaimed. Susan Hayes, shared stories of rendezvous with Dr. Sheppard in his car and at his office, and of spending time with him in Los Angeles earlier that year (McGungale, 2004).

A full 25 days after the murder, an ultimatum was delivered by County Prosecutor Frank Cullitan – arrest Sheppard or the Cleveland police would withdraw from the investigation. The editorial in the *Press* the next day read "QUIT STALLING-- BRING HIM IN (1954)". Later that evening, Dr. Sam Sheppard was arrested. "Apparently the *Press* had its way," Sam stated as he was put into the police cruiser (McGungale, 2004). On August 17th, Sam was indicted by a grand jury on first-degree murder charges.

The case of State of Ohio vs. Sam H. Sheppard was called at 9:00 a.m. on October 18, 1954. The courtroom was packed with mostly reporters, both local and out of town reporters providing national coverage. John Mahon, assisted by Saul Danaceau and Thomas Parrino acted

as the prosecution. William Corrigan led the defense, assisted by Fred Garmone, Arthur Petersilge, and William Corrigan Jr., fresh out of law school. Corrigan immediately motioned to have the venue changed due to prejudice against Sheppard from all of the media frenzy. Common Pleas Judge Edward Blythin stated that the jury should be selected first. The pool of 64 candidates had already been in the media spotlight, with their names, addresses and telephone numbers listed in the newspapers (Schilke). In spite of this, the 12-seat jury was selected in less than two weeks with neither side using all of the peremptory challenges available to them.

The trial began on November 4th, five months after the murder; five months of media frenzy and exclamations of Sheppard's guilt. Deputy Coroner Lester Adelson was first to take the stand. He recounted the autopsy and displayed the grisly photos that the police had taken of the crime scene (Figure 2). Sheppard averted his eyes from the images. During cross-examination, Corrigan was able to coerce Adelson into admitting that he hadn't examined Marilyn's stomach contents, her wounds under a microscope, nor attempted to find evidence of rape despite her clothing being removed in a manner indicative of sexual assault. Her head had also been shaved during the autopsy so no hint of the murder weapon or trace metals could be found.

Nancy Ahern described her discussions with Marilyn about the couple's marital troubles, claiming that they were on the verge of a divorce. The defense team objected on the grounds of hearsay, but Blythin allowed it as an exception. Esther Houk's testimony painted a further picture of the strain in the Sheppard's marriage, describing "rows" between the two. Her description of observing wet footprints leading into the house and up the stairs seemed to corroborate Sam's re-telling of the events of that night, but she continued to recount a time when Sam had discussed how easy it was to fake head injuries. She also could not clearly remember

whether the door had been locked after she and her husband had left that night, but assumed that the door had been unlocked as the Sheppard's did not normally lock it.

Gerber, as he had been in the months leading up to the trial, became the star for the prosecution. With little modesty, he described all of his qualifications in both the medical and legal fields. His testimony centered on his belief that an imprint in the blood-stained pillow was from a surgical instrument. He further went on to describe the instrument that had been responsible for the trauma to Marilyn's head as being heavy, two-bladed with serrated edges and roughly three inches long. The teeth of the blades, he argued, left behind the "blood signature" on the pillow. No efforts were made on the part of Gerber to bring forth such a tool or prove that Sheppard had one in his possession.

Before Corrigan cross-examined Gerber, Judge Blythin asked if the impression could have been made by any other instrument. "…the impression could only have been made by an instrument similar to the type of surgical instrument I had in mind," came Gerber's reply (Linder, The Dr. Sam Sheppard Trial, 2006). Corrigan's cross was unable to force Gerber to yield on this point, instead the defense offered alternative reasoning for the impression – it could have come from blood pooling in the fold between the pillow case and pillow, or from a garden tool or other like instrument.

The forensic evidence in the case, particularly the blood, was the most peculiar aspect of the trial. Mary Cowan, chief medical technologist in the coroner's office for fifteen years, was the chief witness as to the blood found at the crime scene. In a gruesome, violent murder such as this, the murderer would normally be saturated with the blood of the victim, especially if they had been positioned over them and bludgeoning them. Blood was found spattered on the walls and closet doors, and soaked the bed sheet. Yet the only blood found on Sam was a spot on the

knee of his pants and a potential spot on his watch. Though laboratory tests showed that blood evidence could not be removed even after repeated washing, Mahon claimed that Sam must have jumped in the lake to wash the blood off of his shirt and self. Cowan testified that six blood stains were found in the basement and downstairs of the house, but it was neither Type-A like Sam's or Type-O like Marilyn's. Her testing of the blood on Marilyn and Sam's watches and on Sam's pant leg was also inconclusive.

The final witness for the prosecution was Susan Hayes, who delivered details of her affair with Sam, including dates that they spent together, accounts of letters that Sam wrote to her and infrequent discussions by Sam about getting divorced. Fred Garmone asked only one question in his cross-examination: "Miss Hayes, in all your activities with Dr. Sheppard, were you always aware that he was a married man?" Hayes replied with a barely audible, "Yes, sir." With that, on December 1st, the prosecution rested its case.

The defense called upon witnesses from Sam's work and family who claimed that the divorce was Marilyn's idea, and that the couple had been happy in the days leading up to the murder. The doctors who cared for Sam after that night also said that the extent of the injuries he received were consistent with his story. Two witnesses who drove past the Sheppard home at the presumed time of the murder declared that they had seen a tall bushy-haired man lurking outside the residence and that they had notified the police. Sam took the stand from December 9th – December 14th, again retelling what happened that fateful night and professing his love for Marilyn. He admitted to engaging in affairs with other women in addition to Susan, but declined to give the names of any of his mistresses. With that the defense rested.

The closing arguments were long and the prosecution's remarks were full of attacks on Sam, asking all of the questions that hadn't been answered in the five and a half months since the

murder. Why hadn't the dog barked? Why had the burglar left Sam alive? Why hadn't Sam screamed for help as he chased the assailant? Why was Mayor Houk the first he called? How could his son sleep through the assault? Why had Sam been knocked out so easily? The questions were drilled into the minds of the jurors. The bloody pillowcase and Gerber's testimony were again relayed to the jury, and Mahon remarked with biting sarcasm, "Be fair to the defendant. Show him the same mercy he showed his victim (Linder, The Dr. Sam Sheppard Trial, 2006)."

Corrigan and Arthur Petersildge made the closing remarks for the defense. Petersildge returned the prosecutions tactic, asking questions of the jury. Why hadn't they been able to determine how, why, or with what Marilyn had been killed? He called the evidence of the prosecution "flimsy". Corrigan failed to bring to light all the flaws in the evidence, however. The unknown instrument described by Gerber, the unknowns and inconclusiveness of Cowan's testing and Blythin's admissions of hearsay were not key points in his remarks. Instead he chose to describe the lust that Sam had fallen victim to as a lesser sin, and to think of God's gift of freedom, as the trial neared Christmas, and maintain that ideal.

Jury deliberations began at 10:00 a.m. on December 17th. For the first time since the the jury was formed, it was sequestered, though not entirely. The bailiff allowed jurors to use the phone in his hotel room to make unmonitored calls to whomever they pleased, in violation of state law. Finally, just after 4:00 p.m. on December 21st, after one of the longest trials of the century, the jury returned their verdict. They found Sam Sheppard guilty of murder in the second degree, and Judge Blythin sentenced him to life in prison.

Sam and Corrigan put in appeals motioning for a new trial, but were denied each time, even though Paul Leland Kirk, a criminologist, had discovered new evidence who claimed that

testing conducted on the blood from the bedroom where the murder occurred showed the presence of a third person who was neither the accused or the deceased. Attempts at petition for certiorari and an application for writ of habeas corpus were also denied. In 1961, Corrigan passed away and F. Lee Bailey took over as Sheppard's attorney. In July of 1964, Sheppard was finally granted his petition for a writ of habeas corpus. The hearing, conducted in Ohio State District Court involved several pre-trial hearings relating the history of the case, and establishing a long list of issues that were viewed as a violation of Sheppard's constitutional rights. The opinion also highlighted the multitude of media bias that was present prior to and during the original trial, citing several of the major paper's headlines. This Court held that "the prejudicial effect of the newspaper publicity was so manifest that no jury could have been seated at that particular time in Cleveland which would have been fair and impartial regardless of their assurances or the admonitions and instructions of the trial judge (Samuel H. SHEPPARD v. E. L. MAXWELL, 1964)." The court stated that there had been at least five blatant disregards of Sheppard's right to due process as guaranteed by the Fourteenth Amendment of the Constitution, and therefore the trial was null and void.

Sheppard, after serving ten years of his sentence, was granted a new trial in October of 1966. Bailey served as Sheppard's attorney for the trial. The prosecution changed the focus from talk of Sam's affair, not even calling Susan Hayes back to the stand. Gerber went from a key witness for the prosecution, with his damning statements about the "surgical instrument" to a much lesser role. Upon cross-examination, Bailey managed to have Gerber concede that he had searched all over the country, but could not find "an instrument that would fit (McGungale, 2004)." The new evidence for the prosecution came from Mary Cowan, whose testimony had been inconclusive for the most part at the first trial. She claimed that the blood on Sam's watch

could only have come from spatter, placing Sam in the room at the time of the murder. Believing this statement to be evidence enough, the prosecution rested.

Bailey's argument centered on placing doubt in the minds of the jurors, and painting Esther Houk as the killer by producing testimony of witnesses that seemed to create the existence of a secret relationship between Marilyn and Spencer Houk, with Esther killing Marilyn in a jealous rage. The key witness for the defense was Paul Leland Kirk. Kirk delivered his findings upon re-examining the crime scene in 1955. He believed that the blows had been delivered by a left-handed individual, an individual who hated Marilyn Sheppard, and that one of the blood spots was from neither Sam nor Marilyn. He further went on to state the blood spot Cowan pointed out looked like "contact transfer". Bailey brought further doubt about the blood evidence when he showed images of the watch which showed blood patterns on the inside of the watch band that were very similar in appearance to the ones that Cowan said must have come from flying blood. Sam Sheppard never took the stand to once again relate his tale. The trial ended on November 16th, with Sam's acquittal.

While Sam may have been freed after ten years of confinement, the story was far from over. His son Sam Reese Sheppard, formerly known as "Chip", believed whole heartedly that his father was innocent and sought to prove it, even after his father's death in 1970. In 1995, young Sam used his father's estate to sue the state of Ohio for wrongful imprisonment. This required him to prove Dr. Sam's innocence, a much more stringent ruling than not guilty. Young Sam believed that the killer was Richard Eberling, who had worked in the Sheppard's home at the time of the murders as a window washer. Eberling had claimed to have cut his finger on a storm window two days before the murder and that his blood had dripped across the house. He was also found with one of Marilyn's rings in his possession on an arrest for petty theft.

Witnesses came forth to testify that he had told him that he had killed her, and he himself told young Sam that he knew the truth of what had happened that night. His stories were muddled at best, perhaps more farfetched than Dr. Sam's original explanation. Eberling's stories changed often, and his denials increased with them. A string of suspicious deaths had followed Eberling, and he was serving a life sentence in prison for the murder of an elderly woman that took place in 1984 when young Sam's team decided to target him as the primary suspect.

Terry Gilbert, the attorney representing young Sam and his father's estate, wrote this in the petition for declaration of innocence: "The evidence will show that Eberling had motive, opportunity, identity, and access to kill Marilyn Sheppard. A review of all the evidence demonstrates that Dr. Samuel H. Sheppard could not have murdered his wife, had no reason to murder his wife, and was a victim of a misdirected, overreaching prosecution (State of Ohio vs. Samuel H. SHEPPARD, 1995)." In February of 1996, a court order was secured forcing Eberling to yield a DNA sample.

Gilbert sought the help of Dr. Mohammad Tahir, a DNA forensic specialist in Illinois. A set of evidence collected from the crime scene more than 40 years earlier was sent to Tahir for analysis. Tahir stated his concerns over the samples: "The concern was that this is a very small quantity and this is very old. And that we might not be able to get any results (WGBH Boston, 1999)." Due to the severe degradation of the evidence, Tahir chose to conduct the DQA1, a test that works with small quantities, but is limited in its discriminating factor. The test can only determine 8 of 42 potential combinations of alleles, which are present in millions of individuals. Tahir would compare the samples to samples obtained from Marilyn's hair collected during the murder, from Dr. Shepard's exhumed corpse, and from the sample obtained from Eberling. The blood samples that Tahir analyzed were from the stairs and the porch. Upon analysis, the sample

from the porch tested positive for allele 4.1 only, and the sample from the stairs tested positive for the 1.1, 2, 3 and 4.1 alleles. Marilyn's blood had the 1.1 and 1.3 alleles. If the blood stains had been caused by her blood dripping off of the murder weapon as the prosecution theorized originally, then the 1.3 allele would have been found in the test results. Sam's blood contained the 1.2 and 1.3 alleles, excluding him from the blood samples as well. So if the blood was from neither Sam nor Marilyn, could it have been from Eberling? Eberling's blood contained two copies of the 4.1 allele. Therefore, Eberling could not be excluded, and could have contributed to the stains.

The stain from the porch appeared to be a mixture of Eberling and Marilyn's blood, but this result would not be admitted into court for the so-called "third trial". The control dot on the testing strip never changed color, indicating that there was not sufficient DNA for the results to be reliable. The large stain from the closet door yielded another problem with the reliability of the test. It showed a mixture of the 1.1 and 1.3 alleles, but this meant that the 1.2 allele could not be detected, even if it were present. Therefore, Sam's blood may or may not have been present in the stain. The results of all the testing were essentially worthless in the end, due to contamination. Since the samples had been collected years before DNA fingerprinting existed, there was no effort made to protect the integrity of the samples. Alleles that didn't belong to Sam, Marilyn, or Eberling were found in the samples as well. This meant that the presence of the 4.1 allele could have been contributed by someone other than Eberling.

In the end, the DNA evidence didn't stand. The prosecution in the "third trial", led by William Mason, exhumed Marilyn's corpse to obtain fresh DNA and to test the paternity of the fetus she had been carrying at the time of the murder. They claimed that the results of the testing still pointed to Sam as the murderer. In April of 2000, the jury found in favor of the State of Ohio

and the Sam Sheppard case was essentially closed as far as the court system was concerned. Yet even to this day, the question still remains, who killed Marilyn Sheppard?

O.J. Simpson

While the Sheppard trial was noted for its presence in the public, it still pales in comparison with the O.J. Simpson murder case. A 1997 article called it "the most publicized murder case in history (Price & Lovitt, 1997)." The case revolved around many facets that contributed to its media spotlight. A hall-of-fame football player was accused of murdering his ex-wife, Nicole Brown Simpson and her friend, Ronald Goldman. The accused was African-American while the victims were Caucasian. The murders were gruesome and violent, with both victims being stabbed to death repeatedly. The arrest of O.J. Simpson took place after a nationally televised slow-speed pursuit, as O.J., driven by his friend Al Cowlings, claimed that he was going to commit suicide and the police, his lawyers and his friends tried to convince him not to. The pursuit lasted over an hour and took place over 50 miles, all at 35 miles per hour. The whole event was televised, and had over 95 million viewers nationwide (Schuetz, 1999). It was the start of a long trial surrounded by a cloud of publicity, opinions and the on-going race war.

At around 10 p.m. on the night of June 12, 1994, the neighbors of Nicole Brown Simpson testified that they heard a dog barking and wailing. Steve Schwab, who had been walking his dog nearby, encountered an Akita on its leash, but wandering around with no owner in sight and leaving behind a trail of bloody paw-prints. He brought the dog to another neighbor's house. This neighbor, Sukru Boztepe, took the dog for a walk at about 11 p.m. when the dog was becoming more agitated in his home. The dog pulled Boztepe to Nicole's house where he discovered her body in the driveway and waved down a passing patrol car moments later.

Robert Riske, who had been driving the patrol car, discovered Nicole lying face down in a pool of blood on the walkway leading to her house (**Figure-3**). Goldman's body was seen just off the walkway, crumpled up in an alcove beneath a tree and covered in blood. The Simpson's two children, much like Sam Reese Sheppard, were asleep upstairs while the murders occurred.

Figure-4. The bodies of Ronald Goldman and Nicole Brown as shown in a London tabloid (West, 2010).

Both of the victims had been stabbed multiple times, and Nicole's throat had been slit so harshly that her vertebrae had been partially severed. The gruesome violence of the crime became a key aspect in tabloids and also in the prosecution's case. The police quickly made O.J. their chief suspect, based on his history of spousal abuse, evidence found at the crime scene, and his peculiar actions after being told of his ex-wife's death creating a large amount of suspicion. Unable to find the murder weapon, useable fingerprints, any witnesses to the murder, or the sounds of struggle, the prosecution built its case against O.J. on DNA evidence.

DNA testing was still a relatively new science at the time of the trial, only six years after *Andrews* and four years after *Two Bulls*. An assistant Federal public defender from Phoenix, Deborah Williams described DNA as typically, "just an extra nail in the coffin", but that in the O.J. case it "may be the first …I have seen where it is being pulled into the heart of things

(Meier, 1994)." The sheer volume of evidence collected at the crime scene, in O.J.'s Bronco and at his home seemed to provide ample opportunity for DNA testing.

At the crime scene, blood drops were found next to bloody footprints trailing away from the corpses and at the back gate of the condominium where the murders happened. **Table-1** shows all of the bloodstains introduced at the trial, as well as the number of loci tested and type of DNA testing conducted on them and whether it excluded any of the parties (O.J., Nicole, or Ronald). Both restriction fragment length polymorphism (RFLP) and polymerase chain reaction (PCR) tests were conducted. While RFLP tests are much more precise in their exclusivity, they are far more time consuming and require a greater amount of DNA, so fewer samples were analyzed using RFLP testing. All of the samples were analyzed using PCR testing, which is used when small amounts of DNA are present. The testing concluded that O.J. Simpson could not be excluded from the scene of the murders. The prosecution believed that the blood drops containing Simpson's genetic markers had come from a cut on his middle finger (seen in his interview with police the day after the murders) that they speculated was from the knife used in the murders during struggles with the victims, who exhibited defensive wounds. The DNA testing was conducted by the LAPD lab, Cellmark, and further testing was conducted at the California Department of Justice in Berkeley. Cellmark, together with Lifecodes, was one of the first labs to provide DNA testing using Alec Jeffrey's commercialized "DNA fingerprinting" technique. Cellmark (Germantown) became the first private forensic testing lab to obtain accreditation from the American Society of Crime Laboratory Directors in 1994. The California Department of Justice lab in Berkley had been accredited in 1993.

Table 1. Blood Samples from the Bundy Crime Scene (Linder, 2000)

Location of Stain	Number of Loci Tested – RFLP	Number of Loci Tested – PCR	Person Not Excluded
Pool of blood by Nicole Brown Simpson	0	1	Nicole Brown Simpson
Drop of blood by Nicole Brown Simpson	0	7	O.J. Simpson
Blood drop on the walkway (item 48)	0	7	O.J. Simpson
Blood drop on the walkway (item 49)	0	6	O.J. Simpson
Blood drop on the walkway (item 50)	0	7	O.J. Simpson
Blood drop on the walkway (item 52)	5	7	O.J. Simpson
Impression of a shoe	0	5	Nicole Brown Simpson
Drop of blood from Goldman's boot	5	6	Nicole Brown Simpson and Ronald Goldman
Sample from Nicole Brown Simpson's Fingernails	0	7	Nicole Brown Simpson
Blood from the back gate (item 115)	0	2	O.J. Simpson
Blood from the back gate (item 116)	0	2	O.J. Simpson
Blood from the back gate (item 117)	0	2	O.J. Simpson

Many blood samples were found at O.J. Simpson's Rockingham property and in Simpson's Bronco. At Simpson's property, an extra-large dark, cashmere-lined Aris Light leather glove was found, the pair of which had been discovered at the crime scene. A pair of dark, bloody socks was also found crumpled at the foot of Simpson's bed. Blood was on the Bronco's driver's side door, on both the inside and outside, and inside on the carpeting, center console, steering wheel, and instrument panel (The Associated Press, 1996). The results of the DNA testing on these blood stains are shown in **Table 2**.

Table-2. Analysis of Blood Samples from the Rockingham Estate and Simpson's Bronco (Linder, 2000)

Location of Stain	Number of Loci Tested – RFLP	Number of Loci Tested – PCR	Not Excluded
Trail of blood from Rockingham property (item 6)	0	2	O.J. Simpson
Trail of blood from Rockingham property (item 7)	0	5	O.J. Simpson
Foyer at the Rockingham property	5	6	O.J. Simpson
Master bathroom floor of Rockingham property	0	1	O.J. Simpson
Glove found at the Rockingham property			
Inside/back of wrist	0	1	Nicole Brown Simpson and Ronald Goldman
Inside/back of index finger	5	2	Nicole Brown Simpson and Ronald Goldman
Inside/back of middle finger	5	2	Nicole Brown Simpson and Ronald Goldman
Inside/back of ring finger	8	2	Ronald Goldman
Inside/back of hand	5	2	Nicole Brown Simpson and Ronald Goldman
Inside by wrist notch	0	2	O.J. Simpson and Ronald Goldman
Outside near wrist notch (item G-11)	0	1	O.J. Simpson, Nicole Brown Simpson and Ronald Goldman
Outside near wrist notch (item G-12)	0	1	Nicole Brown Simpson and Ronald Goldman
Stitching/wrist notch	0	1	O.J. Simpson, Nicole Brown Simpson and Ronald Goldman
Inside/back of cuff	0	1	Nicole Brown Simpson and Ronald Goldman
Socks found at the Rockingham property			
Ankle	14	7	Nicole Brown Simpson
Near ankle (item 42-B1)	0	2	Nicole Brown Simpson
Near ankle (item 42-B2)	0	2	Nicole Brown Simpson
Upper sock/opposite side	0	2	O.J. Simpson
Upper sock/same side	9	2	O.J. Simpson
Upper toe	0	2	O.J. Simpson
O.J. Simpson's Bronco			
Interior of driver-side door	0	1	O.J. Simpson
Instrument panel	0	1	O.J. Simpson
Driver-side carpet	0	1	O.J. Simpson
Steering wheel	0	6	O.J. Simpson and Nicole Brown Simpson
Center console (item 30)	0	2	O.J. Simpson
Center console (item 31)	0	2	O.J. Simpson

Driver-side wall	0	1	O.J. Simpson
Driver-side carpet	0	1	Nicole Brown Simpson
Center console (combination of the following three)	4		O.J. Simpson
Center console (item 303)		2	O.J. Simpson
Center console (item 304)		2	O.J. Simpson
Center console (item 305)		2	O.J. Simpson

There were a total of 45 blood stains tested, and the testing showed that O.J. could not be excluded from the majority of the blood stains found at the crime scene, in his car, and at his property. Several of the stains, especially on the gloves found at his property, showed genetic markers of the two victims, as well as O.J. One of the drops of blood from the driveway that had RFLP analysis conducted on it produced a 1 in 170 million match to O.J.'s blood (Wang, 2001). With so much DNA evidence, and the apparently clear results of the test, the prosecution felt that they had a very strong case against O.J., despite being unable to locate the murder weapon or any witnesses to the murders. The defense had to resort to the method that had been undertaken since *Andrews* – they had to refute the DNA evidence.

With a "dream team" of high-powered defense attorneys, including F. Lee Bailey, Robert Kardashian, Robert Shapiro, and Johnnie Cochran, O.J. had at his disposal a team capable of finding any methods they could to discredit the prosecution's evidence. Attorneys Barry Scheck and Peter Neufeld, both specialists in DNA cases were brought on to assist, as well as Dr. William C. Thompson, Professor, Department of Criminology at University of California Irvine, and Dr. Henry Lee of the Connecticut State Police Forensic Science Laboratory. The defense team made short work of providing alternative reasons as to why Simpson's blood had been found. They claimed that he may have cut himself while looking for his cell phone in his Bronco the evening that the murders occurred, accounting for the blood in the Bronco and at the Rockingham estate.

The main case made by the defense dealt with ineptitude and bias by the police, the criminologists, and Cellmark. Cellmark had made errors in two independent proficiency tests in 1988 and 1989. Forensic Science, the laboratory hired by the defense team as a consultant, also erred its proficiency test in 1988. The courts had also rejected the company's results in four trials since 1987. Officials from the company stated that those issues had been corrected long ago, noting that there had been 326 trials since 1987 where their DNA results had been allowed. Dr. Thompson stated that, "Cellmark Diagnostics doesn't always do the best work." In contrast, Suzanne Childs, a spokeswoman for the Los Angeles County District Attorney's Office called Cellmark "one of the most experienced and distinguished laboratories" doing DNA testing (Meier, 1994). Dr. Robin Cotton from Cellmark was cross-examined by Neufeld for six days. Neufeld continued to note the two errors in the past and the small sample size of African-Americans used in testing for individuals with all of the same genetic markers as Simpson, and Cotton argued against him every step of the way, to the point where Judge Lance Ito became agitated with both the lawyer and the witness (Court TV, 2004).

The witness representing the California Department of Justice's DNA laboratory was Gary Sims. He testified that the lab had also conducted RFLP testing, but used a different procedure than Cellmark, and still arrived at the same results. Sims presented the results of the testing on the socks, as well as the blood found in the Bronco and on the Rockingham glove. He also testified that of the 108 samples tested in the case, including substrates, only a few were completely used up. This meant that the defense could also have conducted DNA testing. The prosecution put the question of, "Why hadn't they?" in the minds of the jurors and spectators. Sims placed the odds of the blood on the sock coming from someone other than Nicole Brown Simpson at 1 in 21 billion (Cellmark put the value at 1 in 9.7 billion). Scheck handled the cross

on Sims. Scheck focused on the defense's evidence tampering and ineptitude theory in his questioning. Establishing that only a very small sample was necessary for DNA testing, Scheck claimed that improper evidence handling by the LAPD, such as using unclean gloves or unsterilized tools, could have contaminated the samples. Sims conceded that he could not with certainty say how or when the blood had got on the sock. Scheck's questioning was designed to be complex and technical, confusing the spectators, jury, and sometimes tripping up Sims himself. When asked by Judge Ito if Sims understood the factors in the question posed by Scheck, Sims replied, "About half of it (Court TV, 2004)." California Department of Justice criminalist Renee Montgomery also testified on the DNA evidence, particularly the results of the D1S80 test, a cutting-edge PCR test. She stated with certainty that the results of the testing were accurate and that she was confident with the results, and she was capable of answering the questions of her cross-examination with more complex technical responses than Sims had been able to.

Scheck scored points for the defense on his cross-examination of Collin Yamauchi, who performed the majority of the initial testing on what was seen as key evidence against O.J. Yamauchi testified that blood had spilled onto his glove while handling a vial containing a sample of O.J. Simpson's blood. Scheck alleged that this could have been transferred to the Rockingham glove. Yamauchi's admission that he could not see blood spots on the socks was also a strong point, while it coincided with the prosecution's theory that the stains were not readily visible, it also could help support the defense's theory of evidence tampering. Scheck hit further when Sims resumed his testimony by calling to attention the presence of substantial bacterial degradation caused by plants and soil in the samples taken from the walkway on June 13, but none was seen in the samples taken from the back gate on July 3, even though plants can

be seen against the gate in crime scene photos. The combination of this factor with the amount of time that passed between the collection of the evidence on June 3rd and that from the back gate three weeks later left ample room for planting of evidence, Scheck claimed.

Although no direct evidence of evidence tampering was presented by the defense, the prosecution's supposedly solid DNA evidence had been torn apart by Scheck and the defense's "Dream Team". Furthermore, detective Mark Fuhrman, who had been responsible for discovering the gloves at the crime scene and at the Rockingham estate, was quickly turned into a villain by F. Lee Bailey. When asked by Bailey if he had used the word "nigger", Fuhrman denied using the word in the past ten years. Four witnesses and an audio tape were brought forth showing that Fuhrman had indeed used the word. In the taped interview from 1985, Fuhrman had used the word over 41 times, including such statements as, "You do what you're told, understand, nigger?" and bragging about torturing black gang members saying, "we had them begging that they'd never be gang members again, begging us (Linder, Simpson trial: The DNA Evidence , 2000)." This elicited a felony conviction of perjury for Fuhrman for lying on the stand about not using the word in ten years and caused condemnation of him across all spectrums, including by the prosecution.

The combination of Fuhrman's racism and the faulty evidence handling exhibited by the crime lab and police forensic teams, corroborated the defense's theory of planted evidence. The testimony delivered by Yamauchi and Fuhrman had essentially done irreparable damage to what the prosecution had thought was an air-tight case supported by very strong DNA evidence. On October 3, 1995, the verdict was in. The jury found Simpson not guilty and he was acquitted. The jury consisted of 9 African-Americans, 1 Hispanic and 2 Caucasians, 10 of whom were

women. Some of the other facts about the jury that were viewed as possible factors in their decision included:

1. Five thought it was sometimes appropriate to use force on a family member – it was argued that this would nullify the testimony that painted O.J. as an abusive and controlling husband.

2. Five reported that they or another family member had had a negative experience with the police – upon hearing Fuhrman's testimony and the planted evidence theory painted by the defense, this could have influenced the decision.

3. Nine thought that Simpson was less likely to be a murderer because he was a professional athlete – the bias of celebrity standing as an athlete had led the public to have a picture of him as a hero, incapable of committing such a heinous crime

(Linder, Simpson trial: The DNA Evidence , 2000):

The O.J. Simpson criminal case showed that despite having an overwhelming amount of DNA evidence allowed in court, the trial can still be decided by other factors including the confidence the judge or jury has in how the evidence was collected, not just how it was analyzed. The case brought to the forefront the importance of proper evidence handling techniques and laboratory procedures. It was also one of the first cases to bring DNA to the forefront and make it a key element in the eyes of the public due to the media spotlight on the trial. Even so, it seemed that the DNA still took back seat to the characters in the trial, making court proceedings seem more like a circus at times. Johnnie Cochran's famous statement about the prosecution's failed attempt to have one of the crime scene gloves fit OJ in court, "If it doesn't fit, you must acquit", helped convince the jury of reasonable doubt and entered popular culture. Its parody on South Park with the "Chewbacca defense" became a term used by forensic scientists and criminologists referring to the techniques used by defense attorneys to "razzle-dazzle the jury about how complex and complicated the other side's evidence or probability estimates are

(O'Connor, 2006).” The so-called “Chewbacca defense” and the propagation of media hysteria have continued to create sensational court cases. OJ was later found guilty and liable for the two deaths in a civil case based on the “preponderance of evidence”, a lesser standard than for criminal trials.

The Murder of Meredith Kercher

The murder of a pretty, young female student attracts the attention of the media. The murder of a pretty, young female British student in Italy causes the story to spread across countries. The murder of a pretty, young female British student in Italy by a pretty, young American student creates an international debacle. Top it all off with police speculation that the murder had occurred because the British student had refused to participate in a Satanic ritual orgy, and all the ingredients for a media spectacle and a sensational case are present.

November 2, 2007. Police discover the body of Meredith Kercher in the cottage she shares with Amanda Knox and two Italian women in the same age range, Filomena Romanelli and Laura Mezzetti. Kercher was half-clothed, saturated with blood, and lying on the floor of her bedroom, with a duvet wrapped around her. The presence of the duvet led investigators to believe that the killer had either known Meredith, been unable to stand the sight of the dead body, was unable to stomach sexual violence, or felt some type of remorse. She had been stabbed three times in the neck, the first two wounds were shallow, but the third was three-inches wide and three-inches deep (Rich, 2011). Although the carotid artery had not been severed, she had been left to bleed out. The coroner later determined the cause of death to be a combination of blood loss and

asphyxiation (Falconi, 2009). Police believe she received that fatal wound sometime between 9:15 pm and midnight on November 1 (Foster & Owen, 2007).

The coverage of the murder quickly went from Meredith as the victim to Amanda Knox, who quickly became one of the chief suspects. According to Knox, she had been with her then boyfriend, Raffaele Sollecito, at his house when the murders had taken place. She stated that she had left Sollecito's apartment to return to her own to shower (**Figure-4**), change clothes and retrieve a mop, since Sollecito had faulty plumbing and his sink always leaked (Rich, 2011).

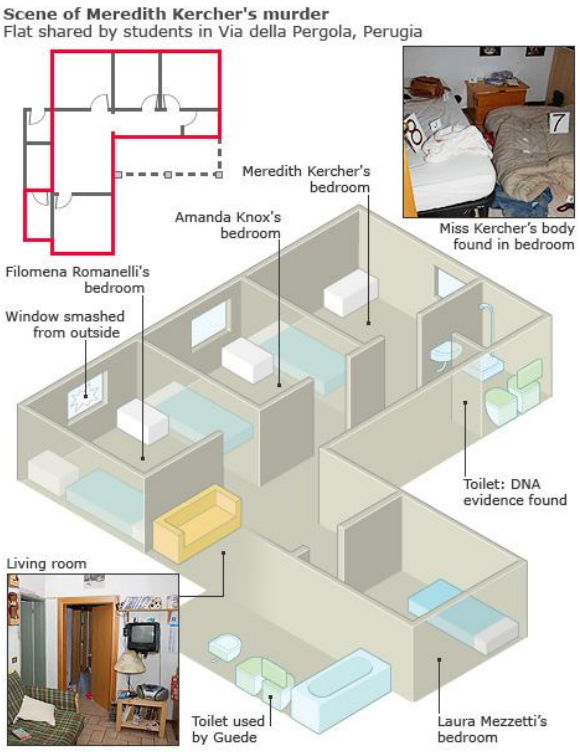

Figure-5. Schematic of the Villa and Location of Crime Scene.
(Murder scene: Meredith Kercher's Italian flat, 2009)

Knox arrived back at the cottage at 7 Via della Pergola at 10:30 am. Knox noticed when she arrived that the front door was ajar and upon calling out, no one responded. Romanelli and Mezzetti had been away for the night and still had yet to return, and Kercher's door had been

closed, leading Knox to believe that she was sleeping. It was after the shower that Knox noticed that there were bloodstains in the sink and on the floor of the bathroom. She speculated that "perhaps Meredith was having menstrual issues and hadn't cleaned up yet" in an e-mail sent to friends and family two days later (Rich, 2011). Knox phoned Romanelli to inform her of her strange findings and left the apartment, returning to Sollecito's. Knox's story changed soon and often. When interviewed earlier, Sollecito claimed that she had indeed spent the night at his flat, and that he had been on his computer while she had been reading; yet during interrogation on November 5th, he stated that he had been smoking marijuana and could not be positive that Knox had not left while he slept.

In her second telling, that same night, Amanda claimed that she had been at the apartment at the time of the murders, and that Meredith had been screaming so loud that she had to cover her ears. This account corroborated police reports of grainy closed-circuit footage from the neighborhood that appear to show Knox returning to the villa around 8:45 p.m. Knox accused her boss, 44 year-old Congolese immigrant Patrick Lumumba, of being the intruder. No lawyer was present when she made these comments, so they could not be admitted as evidence at trial. Knox, Sollecito, and Lumumba were all placed under arrest. Lumumba was later released do to a lack of evidence against him after two weeks in prison. In a civil suit against Knox for defamation, Lumumba was awarded €40,000 (Amanda Knox guilty of Meredith Kercher murder, 2009).

A new suspect emerged two weeks after the murder, when DNA from a bloody fingerprint and from the body at the crime scene was matched to Rudy Guede, who had his DNA on record for former arrests for theft and small-time drug dealing (Squires, 2009). At the time, Guede was still considered the fourth suspect as his bloody handprint had been found on

Kercher's pillow (Dempsey, 2010). Guede was arrested on November 20 in Germany for traveling on a train without having a ticket. He claimed that he had been returning to Italy to turn himself in (Owen, Fourth Meredith suspect arrested in Germany, 2007).

The evidence quickly racked up against Guede. DNA matching his was found on Meredith, as well as inside her. Other biological evidence was also found on Kercher's shirt, handbag, bra, and, as mentioned before, her pillow. The results of testing a stain, believed to be sweat, on the handbag revealed the presence of a male chromosome, and Meredith's blood was also found in the handbag. This led the police to construct a theory of theft as a new element to the case. Guede's DNA was also found on toilet paper in one of the bathrooms of the flat. The bra clasp that was cut away from Meredith's bra was also found to have DNA evidence matching Sollectio, the prosecution claimed (Pisa, Meredith Kercher Murder: New DNA Clue, 2008). With all of the evidence mounted against him, Guede opted for a "fast-track" trial, trading his right to challenge the evidence in favor of a lighter sentence if found guilty. Guede admitted to being in the flat, but claimed that he had scheduled a date with Kercher for that night (Owen, 2008). In the course of the night, Guede claimed to have gotten sick from eating a kebab, and that is why he was in the bathroom. While in the bathroom, he heard Meredith scream, but had not heard the assailant enter or a window break because he had on his headphones and was listening to his iPod (Owen, 2007). Guede then stated that he saw an unknown Italian man assaulting Meredith. The man fled saying, "*T rovato negro, trovato colpevole; andiamò* (Ruotolo, 2008)," Italian for "Found black, found guilty; let's go." Guede attempted to staunch the bleeding, but fled because he was scared (Owen, 2007). Guede was sentenced to 30 years for the murder and sexual assault of Meredith Kercher, and acquitted of charges of theft. His

sentence was reduced by fourteen years after his first appeal because he apologized to Meredith's family for failing to come to her rescue (Press Association, 2010).

A shoe print found on a pillow underneath Meredith's body was said to belong to a woman with a size 36 to 38 shoe. Amanda Knox's shoe size is 37 (Pisa, 2009). The footprints had been revealed by Luminol. A judge concluded that the print had come from Knox's bloodied shoes (Massei, 2010).

A 6.5 inch long knife was found in Sollecito's flat with Sollecito and Knox's DNA on the handle and Kercher's DNA on the blade (Amanda Knox Case Turns on Sharply Disputed Forensics, 2009). The prosecution claimed that this was the knife used to murder Kercher. Police officers and forensic experts said that the knife had looked as though it were cleaned, with tiny scratches on the sides indicating scrubbing (Nadeau, 2009). The spot of DNA on the blade that was believed to be from Meredith was too small to be tested again.

There were also five bloodstains in the house that contained the DNA of both Knox and Kercher. One of these drops was found in Romanelli's bedroom using Luminol. The window in Romanelli's room had also been broken, but the glass from the window lay on top of her dresser and the clothes had been pulled from its doors, perhaps indicating a staged break-in. Nothing was taken from Romanelli's room either, creating another peculiarity. Why would a thief enter through Romanelli's room, only to take a few items and a relatively small sum of money from and murder Meredith? The remaining blood spots were found in the bathroom that Meredith and Amanda shared.

It was a case like O.J. and Sam Sheppard's - no witnesses to the murder, mass media reporting both in favor of Knox's innocence and her guilt, shaky motives, circumstantial evidence, and no murder weapon could be found. As in the Sheppard case, Italian juries are not

sequestered, leaving them open to read any media about the trial, whether it is opinion or fact. Also, like the Sheppard case, Knox was found guilty after a long trial and sentenced to 26 years in prison. Yet, she could soon be acquitted and released, for the DNA evidence has been determined recently to be lacking credibility.

In the first trial, Judge Giancarlo Massei had refused DNA testing by an independent group. On this grounds Knox secured her appeal. Knox and Sollecito's joint appeal began late in 2010. On December 18 of that year, the judge ruled that the DNA evidence would be re-examined by independent experts. Two professors from Rome's La Sapienza University were selected to conduct further testing on the bra clasp and the knife (Pisa, 2010).

The results of the two independent experts were filed in a 145-page report, and concluded that the manner in which the DNA evidence was collected and analyzed fell below international standards and may have been contaminated. The initial testing on the knife was deemed unreliable because it did not follow the established protocols for low-copy number DNA analysis. "The genetic profile, as obtained, appears unreliable because it is not supported by scientifically valid analytical procedures," and so cannot be positively identified as belonging to Ms. Kercher, the report said (Povoledo, 2011). The independent experts testified on July 25, 2011 that they had found no traces of blood on the knife. Instead, traces of starch were found. The question of whether starch traces could be discovered had the knife been cleaned as the prosecution had previously claimed was answered in the negative (Fisher, 2011).

The bra clasp, which was collected 46 days after Meredith's murder, was shown to have been moved around several times during crime scene videos, and its handling was deemed improper, potentially creating contamination. "The exhibit was retrieved 46 days after the crime, in a context that was highly suggestive of ambient contamination," the report said (Rizzo, 2011).

The experts suggested that because its handling was so poor, the clasp should be excluded from evidence (Amanda Knox Family: DNA Testimony Puts Her 'Closer to Freedom', 2011). The report also concluded that the police conducting the evidence had not worn hairnets and had used dirty gloves (much like Yamauchi in the O.J. case almost 17 years prior). Knox's appeal will resume in two months (White, 2011).

Chapter-4 Conclusions

In each of the three cases previously discussed, DNA played a role. It was not however the role most often exhibited by television portrayals, helping ensure that the guilty are convicted and the innocent are let free. In these cases, the DNA evidence often took a back seat to the media frenzy that surrounded the trials. It is not the victims of these sensational cases who receive the majority of this publicity, but rather the accused, characters whose vilification and propagation can serve to draw much greater readership or viewership, especially if they are a celebrity.

All three of these cases have demonstrated the necessity of keeping this media portrayal and public opinion out of the court room. They have also indicated just how important proper handling of DNA evidence is. If too much time is allowed for degradation, if proper protocols such as bagging the evidence in paper bags; not swabbing evidence with clean new Q-tips; not wearing hairnets, booties and clean gloves; and not conducting control tests, what was formerly seen as clearly damning evidence in trial can turn into worthless evidence. A good deal of time in these trials was spent on the testimony of expert witnesses and presentations of DNA evidence, and, consequently, a great deal of money was spent on affirming or denying its validity.

The police and criminologists investigating these cases should therefore ensure that they are maintaining all standard protocols, or the testimony of the prosecution can quickly be seeded with doubt by a savvy defense team raising reasonable doubt. In an era where DNA is thought of in terms of depictions based in science-fiction, the focus has shifted from arguing for its admission in the courts, to solidifying its validity for a public both eager for lots of DNA evidence to be presented and easily skeptical should be wrongdoing be brought to light by the defense team. The burden, now and as always, falls upon the prosecution and the following of accepted international protocols designed by review boards. This will help to prove the validity of DNA evidence beyond a reasonable doubt.

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Chapter-5: DNA Database Ethics

Machell Williams

The development and expansion of databases containing DNA profiles at the local, state, and national levels have greatly enhanced law enforcement's ability to solve cases. Convicted offender databases store hundreds of thousands of previously convicted individuals profiles against which DNA profiles developed from crime scene evidence can be compared. So DNA databases have greatly facilitated the solving of crimes. But whose DNA should be placed in these databases? Should everyone's DNA profile be entered (at time of birth) to enhance our ability to solve crimes? Or is that a privacy violation? Can medical predisposition information be hacked from forensic databases? The purpose of this chapter is to describe what DNA databases are, and to discuss the controversial topic of whose DNA should reside in them.

CODIS

Because individuals committing a crime are often repeat offenders, having a DNA database containing the profiles of individuals previously convicted of high repeat offender crimes (sex offenders, violent felons) serves to compare profiles obtained from crime scenes. The world's largest DNA database is the FBI's Combined DNA Index System (CODIS). CODIS permits the cross-comparison of DNA profiles obtained from biological evidence found at crime scenes (DNA Initiative, 2011a). And even if a perpetrator is not identified through the database, by comparing profiles from various crime scenes, it can help determine if they are related and performed by the same individual, even if his identity is not yet known. Linking can aid an investigation by broadening the pool of suspects or by tracking suspects between states.

CODIS is actually a layered database containing multiple levels. Local databases store information from local crimes, which are linked to state computers that share crime information between cities, which are linked to the national database which stores information between states. The core of the national DNA database was established and funded by the Federal Bureau of Investigation (FBI), and developed specifically to enable public forensic DNA laboratories to create searchable DNA databases of authorized DNA profiles. The CODIS software permits laboratories throughout the country to share and compare DNA data (DNA Initiative, 2011b). In addition, it provides a central database of the DNA profiles from all user laboratories. A weekly search is conducted of the DNA profiles in this national database, known as the National DNA Index System (NDIS), and any resulting matches are automatically returned by the software to the laboratory that submitted the DNA profile.

CODIS uses two indexes to generate investigative leads. The convicted offender index system contains DNA profiles of individuals convicted of specific crimes ranging from violent misdemeanors to sexual assault and murder. Each State has different "qualifying offenses" for which persons convicted must submit a biological sample for inclusion in the DNA database (State Laws, 2010). The forensic index contains DNA profiles obtained from crime scene evidence, such as semen, saliva, or blood with which CODIS uses computer software to automatically search across these entries for a potential match. A match made between profiles in the forensic index can link crime scenes to each other, possibly identifying serial offenders. Based on these "forensic hits," police in multiple jurisdictions or states can coordinate their respective investigations and share leads they originally developed independent of each other. Matches made between the forensic index and the convicted offender index can provide investigators with the identity of a suspect(s). It is important to note that once an "offender hit"

is obtained, conclusions are not automatically drawn, but that information typically is used as probable cause to obtain a new DNA sample from the suspect so the match can be confirmed before an arrest is made.

The current CODIS software is designed for the storage and searching of short tandem repeat (STR) profiles on 13 core loci (**Figure-1**). This topic was discussed in Chapter-1, but it is important to note here that an individual's entire DNA sequence is not entered into CODIS, this level of whole genome analysis has only been done a few times in history. Instead, in forensic analyses, 13 locations on the human genome are analyzed that were very carefully chosen by forensic geneticists to vary between individuals. The 13 core loci contain no known genetic predisposition data, an important point discussed below.

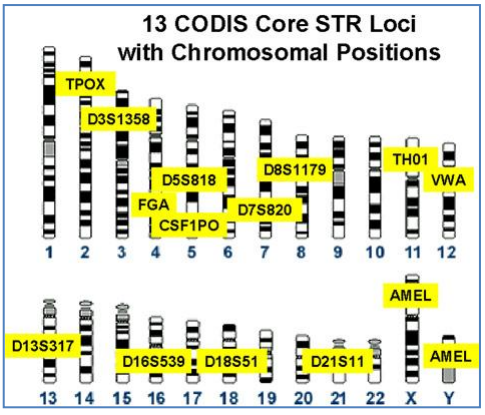

Figure-1: Diagram of the 13 Core Loci. Shown are the 13 core loci (yellow) plus two AMEL sex determination loci whose data constitute a typical CODIS DNA profile. (DNA Initiative, 2011a).

To facilitate data exchange and training, the same CODIS version of the software is used by all participating laboratories at the local, state, and federal levels. Although the main version of CODIS is for handling 13 core loci STR results, a separate software version exists for the entry and searching of mitochondrial DNA (mtDNA) profiles.

The four primary functions of the current CODIS software are:

- **DNA profile entry and management:** to facilitate entering database DNA profiles.
- **Searching:** to perform the database scan.
- **Match management:** to manage the search results. For example, it allows a laboratory to record and distinguish whether a particular match is an offender hit or a forensic hit, and whether the match is within or outside of the state.
- **Statistical calculations:** to enable laboratory personnel to calculate profile statistics, based on the laboratory's or FBI's population frequency data. (DNA Initiative, 2011a)

CODIS and Criminal Cases

The main use for CODIS is to help solve criminal cases. For example, in the case of a sexual assault where an evidence kit is collected from the victim, a DNA profile of the suspected perpetrator is developed from the swabs in the kit. This profile is searched against their state database of convicted offender and arrestee profiles (contained within the Convicted Offender and Arrestee Indices, if that state is authorized to collect DNA from arrestees). If there is a match in the Convicted Offender or Arrestee Index, the laboratory will go through procedures to confirm the match and, if confirmed, will obtain the identity of the suspected perpetrator. The DNA profile from the evidence is also searched against the state's database of crime scene DNA profiles called the Forensic Index. If there is a candidate match to the Forensic Index, the laboratory goes through the confirmation procedures and, if confirmed, the match will have linked two or more crimes together. The law enforcement agencies involved in these cases are then able to share the information obtained on each of the cases and possibly develop additional

leads. So there is a possibility of finding that crimes committed from previous offenders in the database may also have occurred elsewhere.

Genetic Databases

In addition to CODIS which is used for forensic purposes, other DNA databases also exist that are sometimes confused with CODIS. The term 'human genetic database' refers to many different kinds of collections of genetic samples and may include health information (Australian Law Reform Commission, 2010). Genetic samples contained in research collections can include a wide range of human biological materials such as extracted DNA, body fluids, cells and sections of tissue from individuals participating in a genetic study. These databases may include molecular genetic data, standardized clinical data, genealogical data, and information on the health, lifestyle and environment of an individual. In contrast to solving crimes, these databases were established for the purpose of human medical research. Some databases might be maintained for the study of a specific genetic disease, while others might provide information on the migration of the human race during the populating of the pacific islands. The unifying element is that human genetic research databases have been created primarily for the purposes of medical or other human research. In contrast to samples contained in archival pathology collections and other human tissue collections, the samples and information in human genetic research databases are stored with consent for their possible use in research projects, which are submitted to a Human Research Ethics Committee (HREC) for approval, and for which further specific consent is sometimes required.

Much of the research value of human genetic research databases is derived from linkages created between clinical, personal, and genetic information. Examining these linkages is an

important tool in identifying the genetic causes of disease and in other forms of human genetic research. Different forms of genetic research can be conducted using human genetic databases, including:

- linkage studies to identify the gene sequences associated with inherited diseases;
- association studies to find correlations between a disease and a genetic change where there is no obvious pattern of inheritance;
- genetic epidemiology studies of the interaction between genes and environment; and
- pharmaco-genetic studies to determine if there is a genetic basis for certain adverse reactions to drugs. (Australian Law Reform, 2010)

Each of these studies requires access to a different type of human genetic database, or uses databases in a different way, and may raise different issues. Some linkage studies map genetic sequences to identify genetic changes linked to the existence of an inherited disorder, where a distinct familial pattern of disease inheritance can be seen. They require collections of tissue taken from family members and information about members suffering from the disorder. By contrast, association studies require large collections of samples from people with a given condition, combined with detailed medical histories. These studies examine the genetic causes of diseases that do not follow a clear inheritance pattern, and attempt to make statistical correlations between gene sequences and a disease. Large populations are studied because such diseases may show a marked genetic cause in only some individuals, or a weak genetic cause in many individuals. Large populations also increase the accuracy of statistical correlations.

DNA Input into CODIS

Currently, deciding whose DNA is entered into CODIS is decided at the level of the state (National Conference of State Legislatures, 2010). An overview of the state requirements shows that all 50 states require *convicted sex offenders* to provide a DNA sample. States are increasingly expanding these policies to include all felons and some misdemeanors. To date, 47 states require that *all convicted felons* provide a DNA sample to the state's database. At least 15 states currently include certain misdemeanors including sex misdemeanors; other states specify certain sex offenses or child victim offenses. The primary differences between states pertain to *arrestees* and *attempted* crimes.

By 2009, 21 states, Alabama, Alaska, Arizona, Arkansas, California, Colorado, Florida, Kansas, Louisiana, Maryland, Michigan, Minnesota, Missouri, New Mexico, North Dakota, South Carolina, South Dakota, Tennessee, Texas Vermont and Virginia, had passed laws authorizing DNA samples of certain *arrestees*; seven were passed in 2009 including Arkansas and Vermont, among others. Arkansas's qualifying offenses include murder and sex crime arrests. Texas law allows post-indictment samples of certain sex offenders. Minnesota similarly requires a DNA sample after probable cause determination in a charge of selected felonies.

California's Proposition 69, approved by voters on November 2, 2004, requires DNA samples of adults arrested for or charged with a felony sex offense, murder, or voluntary manslaughter, or *attempt* of these crimes. As of 2009, the California measure requires that arrestee sampling be expanded to *arrests for any felony* offense. The same measure expanded DNA testing to all convicted felons. Kansas approved the requirement that felony or drug level 1 or 2 *arrestees* provide a DNA sample, and expanded this mid-2008 to include *all felony arrestees*. New Mexico's law includes arrestee samples from specific violent felons.

Massachusetts currently requires DNA samples for all felonies and some juvenile convictions. The author of this chapter feels that this is not covering a wide enough spectrum of criminal offences. I believe that Iowa has an appropriate balance of requirements, they also require DNA from sex offenders and persons incarcerated but found not guilty due to mental defect. I believe that these individuals should be put in CODIS which increases chances of determining whether these persons have committed previous other crimes in the database.

Privacy Rights

The basis of privacy rights comes from the Fourth Amendment of the U.S. Constitution which states:

> "The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized." (LectLaw.com, 2011)

With respect to forced DNA extraction from an individual, the non-consensual extraction of blood implicates the Fourth Amendment privacy rights, as was shown in the 1989 case of Skinner v. Railway Labor Executives, 489 U.S. 602, 16 (LectLaw.com, 2011). The physical intrusion, penetrating beneath the skin, infringes [a reasonable] expectation of privacy. And currently DNA can be extracted from cheek swabs that do not require needles and blood, so the blood link to the fourth amendment becomes weaker.

The right to privacy is provided to every individual, from free individuals to convicts, but most states argue that when one commits a particular type of crime you forfeit some of these rights the moment you commit that crime. In the case of murder, one could argue that as you

take away someone else's right to life, you forfeit your right to privacy. Thus felons may still have the right to be housed in a semi-private facility, but not to withhold their DNA that could help solve a crime.

Many people are uncomfortable with the idea that their genetic information could become public, they fear that publicizing their genetic information (or for that matter, a hacker obtaining it illegally) could have negative consequences such as denial of health and life insurance, discrimination by employers and fellow coworkers, or the enforcement of eugenics (selective breeding), just to name a few. But as we have stated before, the only information entered into CODIS is information related to the 13 core loci, not information as is entered into scientific genetic databases. The identification information within the 13 core loci, contains no known medical predisposition information, and simply identifies the individual as matching crime scene evidence or not. One cannot extract more information from a database than what was entered into it. Thus, even the best computer hacker cannot get medical predisposition data from CODIS, as this is not the type of information stored in the database.

Although medical information cannot be obtained from CODIS, such information in theory could be obtained from the original stored DNA sample for malicious intentions. A recommendation that could rectify this situation would be to destroy the DNA sample after obtaining the forensic information needed from it, thus making it impossible to be used outside of its intended use.

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PROJECT CONCLUSIONS

DNA fingerprint analysis, with its amazing power for identification, is most popularly known for helping solve criminal cases, but it is also used for solving paternity cases, for helping identify unknown human remains, and for molecular archaeology. Chapter-1 discussed the two main ways of performing DNA fingerprinting. The RFLP technique was historically the first technique used for DNA analysis, and it accurate and reliable, but it is time consuming and requires a relatively large amount of DNA. STR-PCR analysis is the most common technique, and it is fast and sensitive, but prone to contamination.

Chapter-2 discussed the proper methods for collecting and storing DNA evidence to help prevent contamination and degradation. The techniques discussed ranged from recommendations on how to control the original crime scene in layered area, to wearing personal protective gear to prevent contamination, to documenting a chain of custody for each piece of evidence listing every person who has handled that piece of evidence. These methods are absolutely required to ensure the DNA evidence can be admitted into court.

Chapter-3 discussed several landmark DNA court cases that set legal precedence for the admission and acceptance of complex technological evidence including DNA evidence, in US courts. Several early cases were discussed from the *Frye Standard* that requires a new technology to have a general acceptance in the scientific community, to the *Federal Rules of Evidence Rule 702* that requires technology to be reliable. Later cases established the requirement for pre-trial hearings to determine whether the DNA testing had been performed with proper controls, and whether the evidence would be prejudicial.

Chapter-4 discussed several sensational court cases that reminded the reader of the power of DNA testing to solve crimes even decades old. Chapter-5 discussed DNA databases. One of the most important rumors quelled in this chapter is the mistake that all DNA databases are alike, and that CODIS forensic database is identical to a medical database. The authors of this project agree that all persons *convicted* of a felony should be required to submit their DNA to CODIS. This stance is also currently required by all other 50 states. The more profiles input into the database, the more accurate individual locus frequency in various populations, and the greater then chances of solving a crime. However, the authors do not agree with requiring all individuals at time of birth to submit DNA, as those individuals have not yet been convicted of a crime. The authors disagree with privacy rights groups who are against CODIS for fear of medical information leaks, as our research has shown that the information entered into CODIS on the 13 core loci contain no medical information. To quell the skeptics about whether the original DNA sample could be used to gain medical predisposition data, the original DNA sample should be destroyed after gathering the information needed for CODIS, to help ensure no further analysis on is done on the DNA to determine medical predisposition information.

With respect to medical databases, which are very different than CODIS, here the authors agree that medical information could be leaked from this type of database, and agree that no individual should be required to submit DNA to this type of database. Those individuals that wish to contribute samples, should do so with fully informed consent.