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DNA FINGERPRINTING

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By:

Joseph Amatucci	Otilio DePina	Adam Przystas

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APPROVED:

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

ABSTRACT

New technological innovations are not always accepted in the courtroom at first glance. Although DNA fingerprinting is the world's most powerful identifying technology, its acceptance in courts has taken years. This IQP's intention is to provide information about how DNA fingerprinting is performed, to discuss its reliability, document its legal precedents, describe a few sensational cases, and discuss the ethics of DNA databases, as an example of the impact of technology on society.

TABLE OF CONTENTS

PROJECT OBJECTIVES

The purpose of this project was to take a look at DNA fingerprinting, documenting the way it is currently used and its possible uses in the future. The 1st chapter discusses the two main types of DNA fingerprints, and describes the main ways we use the technology. The 2nd chapter focuses on advances in how to handle DNA to prevent contamination or degradation. In the 3rd chapter we look at landmark court cases which changed the way DNA was allowed in the legal system. The 4th chapter looks at sensational DNA cases and the impact DNA evidence had in those very public court cases. Chapter 5 looks at DNA databases to discuss who should be required to submit their DNA, and whether privacy rights are violated. Finally, we authors came to our own conclusions based upon the project research.

DNA FINGERPRINTING: DESCRIPTION AND TYPES

Adam Przystas

Introduction

DNA fingerprinting was first developed in 1984 by Sir Alec Jeffreys (Jeffreys et al., 1985; Meeker, 2004), and involves comparing portions of the DNA molecule found at crime scenes or other sites and comparing them with DNA from known sources. This technology is a highly valuable tool in determining the presence of an individual at a crime scene or other location, and has been argued by some to be the greatest tool in the history of forensic science. Identifying individuals in the past mostly focused on traditional fingerprints, dental records, or blood typing, however each of these methods is flawed in some way when trying to compare one sample to billions. Traditional fingerprints can be surgically altered, as can an individual's teeth, and many people have the same general blood type. Recently, the public has been made more aware of the process of DNA fingerprinting through highly publicized court cases and through popular television and movies, but many people do not understand even the basics behind the science which allows this highly useful evidence to be presented in court, its myriad uses, or the controversies and ethics of using DNA databases. This first chapter will endeavor to take some of the mystery out of DNA fingerprinting, by describing the terminology and applications of DNA fingerprinting in layman's terms wherever possible, as a prelude to subsequent chapters on how such evidence is presented in courts and the controversies of DNA databases.

Introduction to DNA Chemistry and Useful Terminology

The human body is comprised of about 10 trillion cells (Brain, 2000). Each cell in the human body (with the exception of non-nucleated red blood cells) has at its core the deoxyribo-nucleic acid (DNA) of the individual it belongs to residing inside a nucleus. DNA is the blueprint for any organism's genetic makeup, and in the case of human beings, it contains all the genetic information that make us human.

DNA Structure

DNA is comprised of a double helix formation, like two strings twisted together in a long spiral. DNA is made up of base pairs (**Figure-1**) (yellow, blue, red, green colors) and long strands made up of sugar and phosphate (orange in the diagram). A nucleotide represents a base covalently linked to its sugar-phosphate backbone. In DNA there are four types of bases: A-Adenine, C-Cytosine, G-Guanine, and finally T-Thymine. As the nucleotides form weak bonds with each other (adjoining rungs of the ladder in the figure) this forms the double helix pattern which most people associate with DNA. Only specific types of based pairing occur, adenine and thymine, and cytosine and guanine.

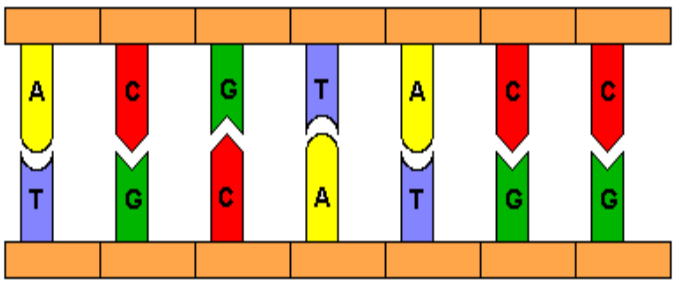

Figure-1: Diagram of DNA Base-Pairing. Individual bases are denoted by the colors yellow (adenine), blue (thymine), red (cytosine), and green (guanine). The sugar-phosphate strands are represented by orange boxes. Note that the interaction of base pairs is weak and can be broken with heat (discussed later), and that specific bases interact with each other. (Brain, 2000)

The double helix formation of human DNA is anti-parallel, that is one strand of the DNA is oriented in the 5' to 3' direction and the opposite strand is 3' to 5'. This means that the

nucleotides are parallel but they go in opposite directions. This anti-parallel bonding makes taking the DNA sequences apart easier for testing as will be discussed later.

"Chromosomes are very long DNA molecules and their associated proteins that carry portions of the hereditary information of an organism" (National Health Museum, 2010). Humans have 23 pairs of chromosomes. Each of these pairs helps to determine certain genetic traits about an individual, such as eye or hair color. One half of each chromosome pair is inherited from the person's mother and the other from the father. Chromosome themselves are very long strands, so to contain them within the nucleus of a cell they are compacted into coiled strands like coiled rope. These strands form an "x" shape within the nucleus (especially during mitosis when the DNA is physically separated into two daughter cells).

DNA Sequence Polymorphisms and Repeats

Approximately 99.9% of DNA is identical for all individuals (University of Arizona, 2006). There are however regions of DNA which vary from person to person. This DNA generally is not required to encode proteins, so is free to differ between individuals, and contains no useful information so is generally referred to as "junk" DNA. However, the random variations appearing within this "junk" DNA allow DNA fingerprinting to exist. These highly interesting areas of variable DNA have been the subject of intense research with respect to their applications to DNA forensics, as the greater number of their locations (loci) analyzed the more accurate becomes the fingerprint. "Polymorphisms" are the differences between DNA sequences between individuals. Sequences with the highest degree of polymorphisms are most useful for DNA testing.

Currently, three major types of DNA repeat sequences are analyzed in DNA testing: restriction fragment length polymorphisms (RFLPs), variable number of tandem repeats (VNTRs), and short tandem repeats (STRs). Each of the three types has certain differences which make them better or worse for use in varying cases. The first type of repeat sequence, RFLP, often pronounced "rif lip" as if it were a word (Davidson College, 2006), represents a sequence of DNA that has a restriction site on each end with a "target" sequence in between. Restriction sites are specific sequences in DNA recognized by restriction enzymes. Restriction enzymes cut DNA at these specific sites, producing DNA fragments of different lengths. The "target" sequence is a sequence of DNA which will bind to a probe to form complementary base pairs. The probe itself is a strand of single-stranded DNA that has been tagged with radioactivity or an enzyme so that it can be detected (Davidson College, 2006). Once the probe has attached itself to its target, that specific DNA fragment can then be detected within a complex mixture of other fragments due to the probe's label. The restriction length polymorphisms themselves are defined by the method by which they are used and found, as they represent the differences in *lengths* between specific DNA fragments flanked by a given set of restriction sites. So for example, a specific DNA fragment that hybridizes to a probe-X might be flanked by two EcoRI restriction sites, and this fragment might vary in length between two individuals.

The second type of polymorphism used in DNA fingerprinting is the VNTR. VNTRs occur when a short nucleotide sequence is organized as a tandem repeat. A tandem repeat occurs when two or more nucleotides form a pattern that is repeated, and the repetitions are directly adjacent (tandem) to each other. The VNTRs used in DNA testing often contain sets of 10-60 nucleotides repeated in areas known as minisatellites. The first discovery of a human

minisatellite DNA occurred in 1980 (Wyman and White, 1980), and since then they have been the subject of intense research for DNA testing.

The third type of repeat sequence is a short tandem repeat (STR). These represent a tandem repeat with fewer than 10 nucleotides (frequently 2-5), and is also known as a microsatellite (The Biology Project, 2000). These base pairs are then repeated in a pattern numerous times in a head to tail pattern. For example, the pattern "aattaattaatt" would be a repeat of the STR "aatt" three times, head to tail. STRs vary between individuals depending on the number of copies of the repeat elements.

STR repreats are used most frequently in current DNA testing because their length is short enough to allow amplification by PCR (discussed below). In a standard DNA analysis, 13 core STR loci are analyzed. These core loci are defined by the FBI for use in the Combined DNA Index System (CODIS) the world's largest DNA database maintained by the FBI (University of Arizona, 2006). All of CODIS STRs are tetrameric repeat sequences, made up of four nucleotides that repeat a various number of times between individuals.

DNA Fingerprinting Types

There are two main types of DNA fingerprinting used today for court cases around the world. Non-amplifying-type DNA fingerprints are used with VNTR and RFLP sequences, while amplifying-type DNA fingerprints are used with STR sequences. Both types of DNA fingerprint analysis have advantages and disadvantages which will be covered in this subsection.

Non-Amplifying-Type DNA Fingerprints

Historically, the first type of technique used to distinguish between different sequences at a locus was a non-amplifying analysis applied to an RFLP (Hill, 2004). This process is also used today when sufficient quantities of sample are available. The first step in this process is to use a restriction enzyme to cut or cleave the DNA at specific locations. This results in fragments of DNA of different lengths. Restriction enzymes recognize specific sequences of nucleotides on DNA and cleave the DNA at these locations. As an example, the restriction enzyme *EcoRI* cuts the target sequence GAATTC after the first G (**Figure-2**).

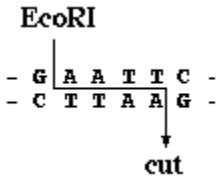

Figure-2: Diagram of the Cutting of DNA by Restriction Enzyme EcoRI. EcoRI cuts DNA strands at the sequence GAATTC after the first G. Note that in this case, the cut is not straight through. (Davidson College, 2006)

Shown in **Figure-3** are the elements of an RFLP, a target sequence flanked by a pair of restriction sites. When this DNA is cut by EcoR I, it produces three restriction fragments (shown in the lower row), only one of which (the center one) contains the target sequence which is then bound to the probe.

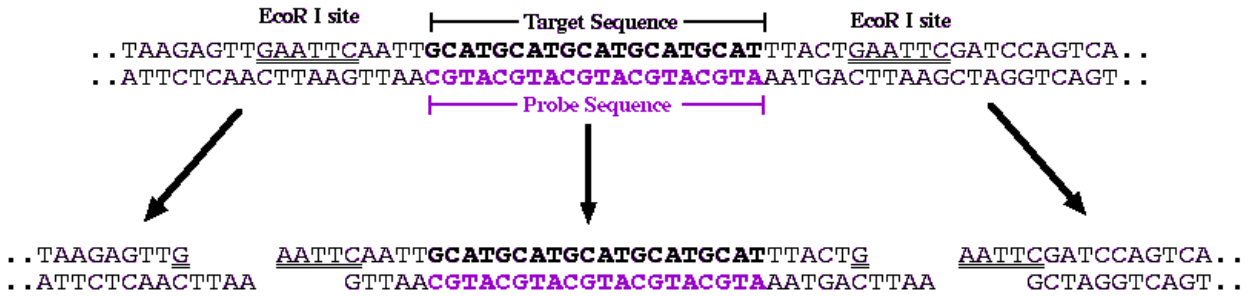

Figure-3: Hybridizing a Probe Sequence to an EcoRI Type RFLP. The two GAATTC *EcoRI* recognition sequences are underlined. The probe sequence in the middle fragment is shown in purple. (Davidson College, 2006)

Over 90 different restriction enzymes have been isolated from different species of bacteria (Lerner, 2006). Each of these enzymes cleaves DNA between different, and specific, sequences of nucleotides. The bacteria use these enzymes to cleave invading foreign DNA, such as plasmids or viruses. In DNA testing, this library of enzymes provides scientists with an important tool for cutting DNA at a variety of specific locations.

Once the DNA has been cut by a set of restriction enzymes, the mixture is then transferred to a gel and electrophoresis is performed. This process uses an electric current to move DNA fragments through a separating sieve such as an agarose or polyacrylamide gel, with the smaller fragments moving fastest. The phosphate component of the DNA backbone has a slight negative charge, so DNA fragments move towards the positive anode (Khalsa, 2004). The DNA molecules are pulled to the positive end of the current but the gel slows them. Smaller fragments have an easier time navigating the mesh and so move farther through the gel. This distance traveled is roughly proportional to the inverse of the of each fragment's length (Lerner, 2006). As a result, shorter fragments travel farther from the origin as they move through the gel. The gel is then stained with ethidium bromide so you can visualize how the DNA molecules resolved into bands along the gel. In the case of human DNA, the pattern of fragments is so complex it usually displays as a smear.

Once the RFLP fragments have been separated on the agarose gel, another step is taken called Southern blotting. Southern blotting is a technique named after its inventor and developer, the British biologist Edwin M. Southern in 1975 (Southern, 1975; Molecular Station, 2007). Southern blotting allows the detection of a specific DNA sequence in a large, complex sample of DNA such as cut cellular DNA. **Figure-4** illustrates the steps in preparing a southern blot in the lab. The first two steps have already been outlined above. Starting in step 3, a nylon or

nitrocellulose membrane is placed on top of the agarose gel in a buffer solution. Pressure is then applied evenly to the gel using suction or a stack of paper towels covered by a weight to ensure even contact between the gel and membrane. Buffer transfer by capillary action from a region of high water potential to a region of low water potential (usually filter paper or tissues) is then used to move the DNA from the gel to the membrane. A positively charged membrane is usually used to allow the negatively charged DNA to bond better (Molecular Station, 2007). If this step is done correctly, the pattern (or smear) of separated DNA fragments in the original gel precisely matches the pattern (or smear) in the membrane. In step 4, a nitrocellulose membrane is baked by exposure to a high temperature (or a nylon membrane is exposed to UV radiation) to permanently attach the DNA to the membrane. In step 5, the membrane is exposed to a radiolabeled probe. This probe is a single-stranded DNA fragment which has the sequence of DNA you wish to detect. The probe is incubated with the membrane to allow the probe to hybridize with the complementary DNA on the membrane. Probes are usually radiolabeled so they can be detected on film; however newer probes are often non-radioactive such as fluorescent or chromogenic dyes (Molecular Station, 2007). The excess probe is then washed off the membrane, leaving only the specifically-bound probe. In step 6, the pattern of hybridization is detected by visualization on x-ray film by autoradiography in the case of a radioactive or fluorescent probes, or by development of color on the membrane if a chromogenic detection method is utilized.

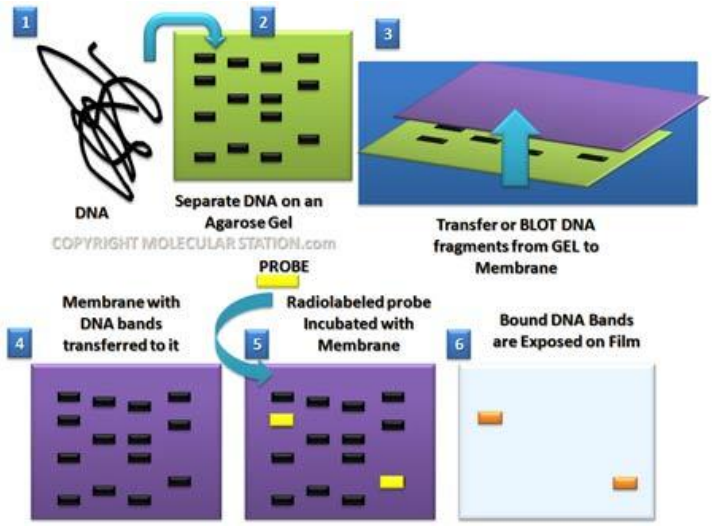

Figure-4: Various Stages of a Southern Blot. Stages 1-6 are discussed in the text above. Overall, the process displays the position of a specific restriction fragment of DNA in a complex mixture (Molecular Station, 2007)

While RFLP analysis was the first type used to analyze DNA, newer more faster and more sensitive methods have been discovered. RFLPs are used much less often than they used to be due to a few key factors. RFLP analysis is non-amplifying so it requires a rather large amount of DNA compared to the STR type we will look at next. Also, with all of the steps required to do RFLP fingerprinting it can take a long time to get the results. The positive side of RFLP analysis is that the results are not strongly affected by contamination, unlike with PCR-type methods. Thus, RFLP type testing is sometimes used in addition to PCR testing when sufficient quantities of DNA are available, and contamination is a potential problem. It should be noted however that RFLP has been almost completely replaced with PCR based testing.

PCR-Type Fingerprints

The second type of DNA fingerprinting is known as amplifying-type DNA testing because of the use of polymerase chain reaction (PCR). PCR is a technique invented by Kary Mullis in 1986 (Mullis et al., 1986) which earned him the Nobel Prize in Chemistry in 1993. PCR is used to take a small sample of DNA and amplify the number of copies of a specific region for further testing. PCR-based testing can not amplify long DNA fragments, so it is used most often to analyze STRs, which have already been discussed.

The process of PCR uses a small sample of DNA to amplify a specific sequence enough to be useable. The process is relatively simple when analyzed step by step. This process allows scientists to create millions of segments of a single DNA strand in a matter of hours. PCR mimics the process of cell division within an organism, but does so inside a test tube. When cells divide, enzymes called polymerases make a copy of the DNA in each chromosome. The first step in this process is to "unzip" the two DNA strands of the double helix (Access Excellence, 1992). As the two chromosome strands separate, DNA polymerase makes a copy using each strand as a template. DNA polymerase also requires two other components, a supply of the four nucleotide bases as precursors, and a DNA primer to act as a start site for DNA replication. DNA polymerases cannot copy a chain of DNA without a short sequence of nucleotides to "prime" the process, or get it started (Access Excellence, 1992). So the cell has another enzyme called a primase that makes the first few nucleotides of the primer, then the polymerase takes over making the rest of the chain.

A PCR vial contains all the components needed for DNA duplication. A piece of DNA template, large quantities of the four nucleotide precursors, large quantities of the DNA primer, and DNA polymerase. The polymerase is the Taq polymerase, named for *Thermus aquaticus*, from which it was isolated (Access Excellence, 1992). This species of bacterium lives near hot

water vents in the ocean floor, and its DNA polymerase has a special structure that allows it to withstand high temperatures. This property is utilized during PCR by allowing the synthesis of DNA at elevated temperatures so it is specifically primed with the DNA primers, unlike at lower temperatures where non-specific priming can occur.

The three steps of the PCR are carried out in the same vial but at different temperatures (**Figure-5**). The first step separates the two DNA chains in the double helix (diagram upper center). This is done by heating the vial to between 90-95°C for 30 seconds. This process is known as denaturation. The DNA primers however cannot bond to the DNA at high temperatures, so the vials are then cooled to 55°C (diagram upper right). At this temperature the primers bond to the complementary sequences flanking the region of DNA to be amplified. This step is called annealing. This process takes about 20 seconds to complete. The final step makes copies of the templates (diagram lower left). The temperature in the vial is raised to about 75°C, and the Taq polymerase begins adding nucleotides to the primer and eventually makes a complementary copy of the template. This set of three steps completes one PCR cycle. The cycle is then repeated 30 or more times in an automated thermocycler (diagram lower right). Each newly created piece of DNA can be used as a new template for the next cycle. Counting in the time it takes to change the temperature in the vial, 1 million copies can be produced in about 3 hours.

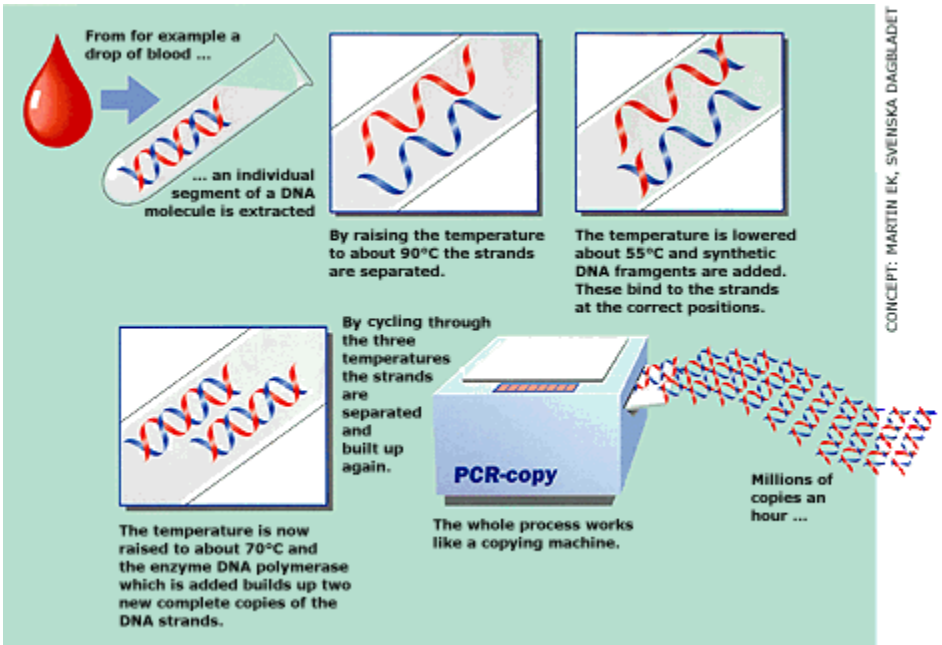

Figure-5: Diagram of the Main Steps of PCR. The three main steps of PCR and their cycle of repeats are described in the text above. (Noble Prize, 2006)

The exponential amplification of DNA during PCR is shown in **Figure-6**. Because each produced DNA fragment can itself serve as the template for further amplification, the process is exponential. Once the PCR process is complete, the size of the amplified fragment, termed an amplicon, is analyzed by electrophoresis. Once again, electric current is used to move the DNA through the sieve material, with the smaller fragments moving further. The fragment migrates according to size, and it movement reflects the number of DNA sequence repeats.

PCR methods today are generally preferred over RFLP because it requires less DNA and is quicker. However, it is also very easily contaminated, so it must be carefully monitored at each step. Since the process is so sensitive, any contaminants in a sample (for example from a collectors own DNA) can also be copied. Due to this, clean room procedures are used when dealing with PCR/STR DNA fingerprinting.

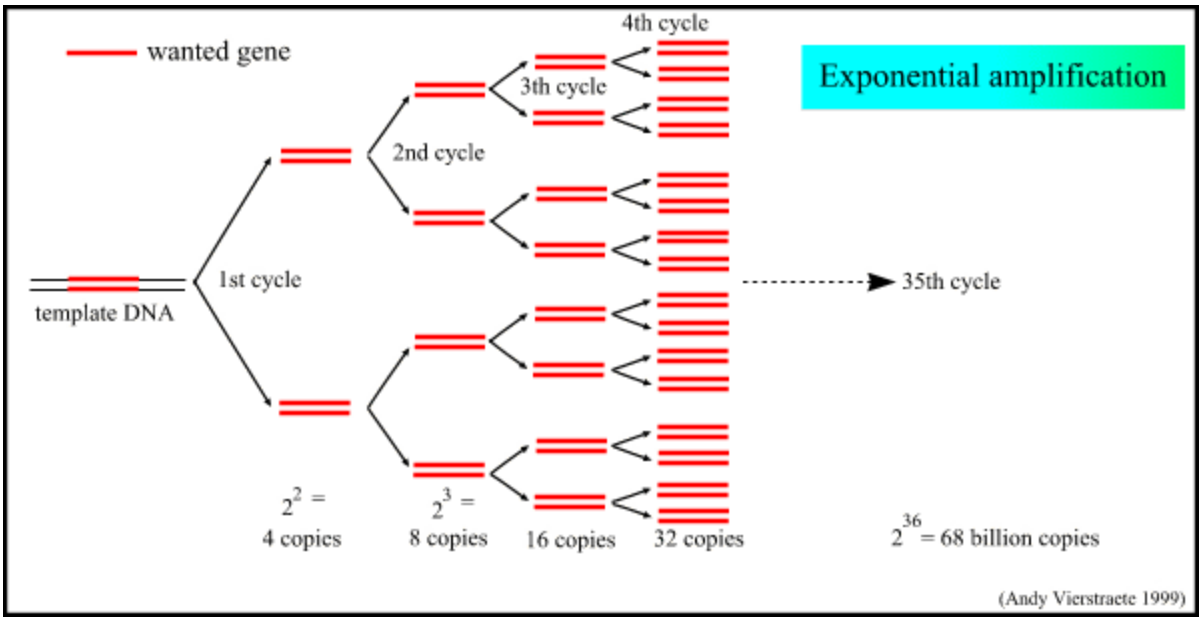

Figure-6: The Exponential Amplification of DNA During PCR. The desired segment of DNA for amplification is shown in red. Since each amplified fragment can serve as a template for further amplification, the production of DNA is exponential. (Vierstnete, 1999).

DNA Fingerprinting Applications

Now that we have looked at what exactly DNA fingerprinting is, how it is done, and the different types, we need to discuss how the technology is used. In this subsection we will look at a few of the applications in which DNA fingerprinting is used today.

Paternity Testing

The most frequent use of DNA testing is paternity testing. This name is somewhat misleading as almost any familial relationship can be tested to see if two people are related, not just parents and offspring. The most common use in this category is to determine who is the father of a particular child. There are two types of paternity testing; the first is prenatal testing, which is done before the child is born. The second is postnatal testing, done after the child is

born. Postnatal testing is usually the recommended method, as prenatal testing can carry a risk of miscarriage (American Pregnancy Association, 2000-2010).

The two types of prenatal paternity testing are amniocentesis and chorionic villus sampling (CVS). Amniocentesis testing is performed in the second trimester, from between the 14^{th}-20^{th} week of pregnancy. In this procedure a doctor uses ultrasound to guide a thin needle into the uterus through the abdomen. The needle collects a small sample of amniotic fluid which is then tested. CVS testing can be done earlier, anywhere from the 10^{th} – 13^{th} week of the pregnancy. In CVS testing, a thin needle or tube is inserted from the vagina through the cervix guided by an ultrasound to obtain chorionic villi. Chorionic villi are small finger-like pieces of tissue with the same genetic makeup as the fertilized egg.

Postnatal testing is much simpler with the sample being obtained either through blood collection or a cheek swab. Umbilical cord collection and testing can also be done, as can other samples (hair, tissue, etc.).

Now that we have looked at how genetic samples are collected for paternity testing, let us look at one example of paternity testing using an RFLP analysis. In **Figure-7,** DNA was extracted from three individuals, mother (Jill), child (Payle), and a supposed father (Jack), and subjected to RFLP analysis. Here we are trying to determine if Payle is Jack's son or not. Because Payle displays a 4.3 kb fragment in common with Jack, it appears that Jack could be the father. The 12.4 kb band appears to have come from Jill.

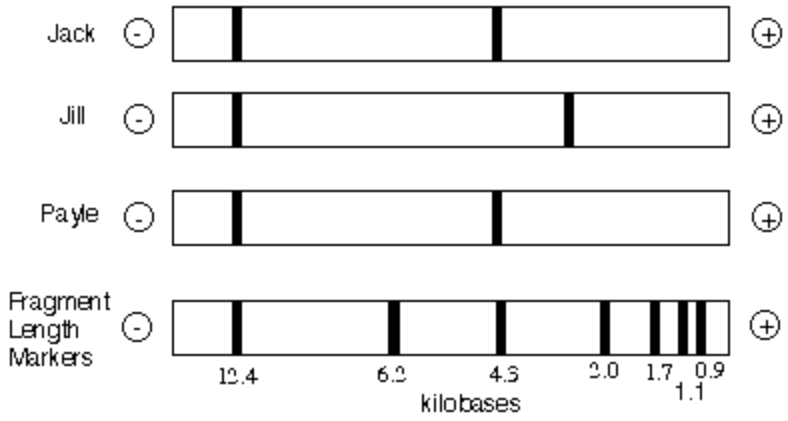

Figure-7: An Example of Paternity Testing by RFLP. Jill is the known mother of child Payle. Jack is the questionable father. (Davidson College, 2006)

However, another man with similar RFLP patterns (producing a 4.3 kb band) could be the father as well. To ensure Jack is the father, more RFLP loci were analyzed (**Figure-8**). Note that in this case, Payle displays a 6.0 kb fragment that did not come from either Jill or Jack, so Jack can not be the father.

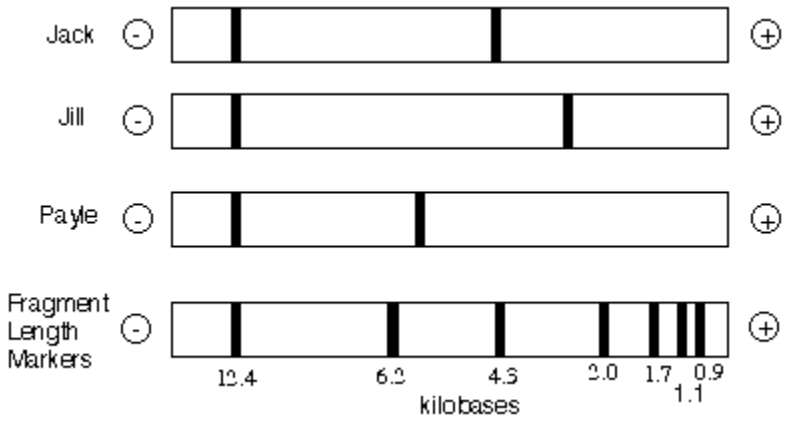

Figure-8: Further Testing of the DNA Samples From the Previous Figure. In this case, note the presence of a 6.0 kb fragment in Payle that is not present in either Jill or Jack, so Jack can not be the father. (Davidson College, 2006)

Molecular Archeology

DNA fingerprinting has also created a new field in archeology, called molecular archeology. This new developing branch of archeology focuses on the analysis of either nuclear DNA or mtDNA (mitochondrial DNA) from archeological sites, using animal or human remains (Christianson, 2000). This approach allows a look into the lives of ancient people, plants and animals. DNA can be drawn from different sources depending on its state. DNA can be gathered from biological remains, skeletal remains, body tissues, and sometimes even fossils. Although a small sample can be used to test for genetic material, there will always be a slight amount of destruction of the specimen. DNA quality is affected by the environment of the specimen. Very cold areas or arid areas are the best preservatives of DNA, the more humid or damp the more decay that will occur and the more likely a sample will be contaminated. For this reason Egyptian mummies and bodies found within ice are both good candidates for DNA extraction.

Molecular archeology specimens should be collected directly at the excavation site if possible, and anyone handling a sample should wear gloves and masks. Tools should be sterilized to avoid contamination. DNA extraction can be done with either UV radiation or through a chemical process which will break down the sample and allow the DNA to remain. Then the DNA is amplified by PCR so it can be more easily studied.

One use in which molecular archeology is currently being used is to identify the thousands of fragments from the Dead Sea Scrolls (Biotechnology Industry Organization, 2009). DNA typing allows scientists to discriminate scrolls written on sheepskin from those written on goatskin. This allows the scientists to reconstruct the pieces as they were originally assembled. DNA typing was also used to identify the remains of Czar Nicholas Romanov II of Russia and

his family, who were executed by the Bolsheviks in 1918. They compared DNA from bones with DNA from blood samples of living descendants of Nicholas II to prove that individuals buried at a site near the execution basement were indeed the Romanov family members. The results of DNA typing also proved that one woman claiming to be the Russian Grand Duchess Anastasia was false.

Another example of molecular archeology was when ancient-DNA expert Svante Paabo gave his colleague Johannes Krause a sample of a 40,000 year old human finger bone (Brown, 2010). He wanted to know whether its DNA was that of a Neandertal or a modern human. The sample however turned out to be neither, representing a new species of ancient human. This marks the first time a new lineage of ancient human has been identified using ancient DNA instead of fossil bones. The finger bone was found in 2008 at Denisova cave in Russia's Altai Mountains. This find suggests that Central Asia was occupied not only by Neandertals and *Homo sapiens* but also by a third, previously unknown hominin lineage.

Criminal Forensics

The final use for DNA fingerprinting discussed here is the one which causes most of the uproar, the field of criminal forensics. This involves the collection of evidence from crime scenes, and comparing it to DNA profiles stored in crime scene databases, or to profiles stored in convicted felon databases. The biggest uses of DNA fingerprinting in criminal forensics is to match potential suspects to DNA evidence left at a crime scene or to help exonerate people wrongly accused of crimes.

Criminal forensics starts with sample collection at the scene of the crime (Byrd, 2000). One of the major factors which determine whether criminal forensics is successful is proper

protection of evidence at the scene. The first person on the scene must properly secure it to keep any sort of contamination from happening. All nonessential personnel should be kept out of the crime scene so investigators can then begin collecting the evidence. The next step is for a crime scene investigator or evidence recovery technician to go over the scene to collect any evidence which may be pertinent to the crime without disturbing the scene itself. This type of evidence can include blood, semen, hair, and nail scrapings, as well as the more common evidence such as traditional fingerprints, fabric impressions, footprints etc. One of the important steps in this process is also documenting the scene accurately before anything is moved or removed, sometimes this can include taking pictures of the scene. As the evidence is collected it must all be properly tagged and logged and packaged so that it remains intact on the way to the lab to prevent potential tampering or degradation. Once the evidence has been collected, it will go to a crime lab where it will be processed.

The crime lab is the place where the DNA will be isolated and analyzed. The DNA profiles obtained here will be compared with profiles from victims or suspects to determine if they were present at the crime. Examples of this type of analysis can be found everywhere from sensational cases such as the O.J. Simpson trial, to small criminal cases in rural areas. Some of these examples will be covered later in this project. One example of criminal forensics which should be noted here is The Innocence Project, which uses DNA testing to free potentially innocent persons from prison if DNA testing was not used in the original trial (Innocence Project, 2010). Using this approach, at least two hundred fifty-five people so far have been proven innocent and exonerated after serving time on death row. These people were convicted in 34 different states and served a combined total of 3,245 years in prison for crimes they did not commit. Criminal forensics and the use of DNA helped to set these people free.

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CHAPTER-2: DNA FORENSICS

Joseph Amatucci

Forensic History

The American Heritage Dictionary defines forensics as "The use of science and technology to investigate and establish facts in criminal or civil courts of law" (American Heritage, 2010). Law enforcement authorities have been employing science and technology in civil and criminal court cases since antiquity. The earliest likely verifiable case is that of Archimedes of Syracuse in the third century BC who used the principals of buoyancy and displacement to prove that a dishonest goldsmith had substituted silver for some of the gold given to him by King Hiero for making the king's crown (Bendick, 1962). One of the earliest written accounts of *medical* forensics in the solving of a crime appeared in a 13th century work by a Chinese judge, Song Ci. In this case, it was determined that a man had been murdered with a sickle, so all of the possible perpetrators were ordered to gather in one location with their sickles. The owner of the sickle which attracted flies because of the blood residue was accused and subsequently confessed (Xiaomin, 2005).

In the intervening years, and with great acceleration in the 19th and 20th centuries, modern science immensely increased the scope and ability of forensic technology (Webb, 1999). The physical, chemical, medical, and biological methods of forensic science are too numerous to list here in their entirety, but most lay people are familiar with long standing forensic methods such as the analysis of fingerprints, tire tread marks, shoe prints, and ballistics. And because of the news media and popular entertainment, increasing numbers of people are aware of more sophisticated techniques such as explosive residue analysis, computer data retrieval, and forensic entomology, etc. (Lotter, 2008).

In the late 20th century, advances in the technology of DNA analysis brought a new and perhaps the most powerful tool ever to the science of forensics, DNA fingerprinting. This technology was initially adopted by molecular biologist Alec Jeffreys from an earlier Southern blot type DNA analysis (Jeffreys et al., 1985a). The first application for DNA fingerprint analysis was the solving of a paternity courtcase in England (Jeffreys et al., 1985b). The first *crime* ever solved by DNA forensics was in England in 1986 with the Colin Pitchfork case when Alec Jeffreys helped police identify the perpetrator in two rape-murders and exonerate a 17 year old boy who had falsely confessed to the crime (Autopsy, 2004). One year later, the first US conviction aided by DNA evidence occurred in Florida when DNA from a sample of the perpetrator's blood was matched to DNA from a semen sample taken from the victim (Andrews v. State of Florida, 1988; Calandro et al., 2005).

Because of its great discriminatory power, and ability to convict and exonerate individuals, DNA evidence has received much scrutiny. The goal of this chapter is twofold, first to illustrate some of the peculiarities of DNA forensics, and second to show what changes and improvements have been made in the techniques and methods of DNA forensics since its first use in the courts to make it less likely to be dismissed as evidence.

DNA Evidence and the Crime Scene

The goal of all good forensics and crime scene investigative work is to identify, collect and preserve physical evidence which can aid in the resolution of criminal cases. In this capacity, all of the practices that constitute good forensics work also apply to DNA forensics. At any crime scene investigation administered properly, after the safety and well being of the investigators and civilians (as well as possible victims) at the scene has been ensured, the

location should be secured, points of entry should be limited and barred, Any individuals who may have been present at the scene should be identified and processed, and further access to the scene should be limited and controlled. The utmost care should be taken to prevent the crime scene from being altered or disturbed in any way, and the original condition of the scene should be recorded with as much written and photographic documentation as possible before the search and collection of physical evidence begins (Technical Working Group, 2000).

Physical evidence is any material or object which can confirm the presence of a suspect at a crime scene. DNA evidence, which has a very great discriminative power, approached only by that of traditional fingerprinting (i.e. fingermark evidence) to positively link evidence with an individual, falls into this general category, but with some significant differences (Williams, 2009). Crime scene investigators need to take these peculiarities into account (discussed below) when searching for, identifying, collecting, storing, and transporting DNA evidence.

Sources of DNA Evidence

In the early 20th century only a few years after the human blood grouping system was first elucidated, modern forensic science's first successful criminal conviction based on the chemical analysis of tissue remains occurred in Germany using human blood residue (Teitelbaum, 1990). So, the collection of forensic evidence from human tissue remains, which is where one would also find DNA evidence, is not new to modern forensic science. However, until the invention of analytical DNA technology, this analysis was restricted largely to serology. DNA evidence far surpasses serology in discriminative power, but more importantly for crime scene investigators, DNA evidence can be extracted from minute remains invisible to the naked eye, and can often be extracted from sources from which physical evidence traditionally would not have been considered or collected (see Table I).

Evidence	Possible Location of DNA on the Evidence	Source of DNA
baseball bat or similar weapon	handle, end	sweat, skin, blood, tissue
hat, bandanna, or mask	inside	sweat, hair, dandruff
eyeglasses	nose or ear pieces, lens	sweat, skin
facial tissue, cotton swab	surface area	mucus, blood, sweat, semen, ear wax
dirty laundry	surface area	blood, sweat, semen
toothpick	tips	saliva
used cigarette	cigarette butt	saliva
stamp or envelope	licked area	saliva
tape or ligature	inside/outside surface	skin, sweat
bottle, can, or glass	sides, mouthpiece	saliva, sweat
used condom	inside/outside surface	semen, vaginal or rectal cells
blanket, pillow, sheet	surface area	sweat, hair, semen, urine, saliva
"through and through" bullet	outside surface	blood, tissue
bite mark	person's skin or clothing	saliva
fingernail, partial fingernail	scrapings	blood, sweat, tissue

Table I: Potential Sources of DNA Evidence. (DNA.Gov, n.d.)

In the early days of DNA forensics, RFLP (restriction fragment length polymorphism) was the most common analytical method used. As discussed in Chapter-1, this method requires relatively large amounts of starting DNA because the longer sequences needed for the analysis are not amenable to amplification by PCR (polymerase chain reaction). Currently and increasingly so, most forensic DNA analysis is performed on STR's (short tandem repeats). This analytical technique relies on much shorter lengths of DNA which are very amenable to

amplification by PCR. These PCR techniques can require 10-50 fold less starting DNA than RFLP. Therefore crime scene investigators can now consider using even the most miniscule amounts of human tissue remains as possible evidence (**Table II**) (Federal Judicial Center, 2000).

Type of Sample	DNA Content	PCR Success Rate
Blood	20,000–40,000 ng/mL	
stain 1 cm x 1 cm	ca. 200 ng	> 95%
stain 1 mm x 1 mm	ca. 2 ng	
Semen	150,000–300,000 ng/mL	
on post-coital vaginal swab	0–3000 ng	>95%
Saliva	1000–10,000 ng/mL	
on a cigarette butt	0–25ng	50–70%
Hair		
root end of pulled hair	1–750 ng	>90%
root end of shed hair	1–12 ng	<20%
hair shaft	0.001–0.040 ng/cm	
Urine	1–20 ng/mL	
Skin cells		
from socks, gloves, or clothing repeatedly used		30–60%
from handled objects (e.g., a doorknob)		<20%

ng = nanogram, or 1/1,000,000,000th of a gram; mL = milliliter; cm = centimeter; mm = millimeter

Table II: The Nuclear DNA Content of Various Tissue Remains and Success Rate of PCR Based DNA Analysis. (Federal Judicial Center, 2000)

Most DNA evidence is obtained from nuclear DNA, but it can also be obtained from mitochondria, organelles present in all eukaryotic cells. Mitochondrial DNA (mtDNA) analysis is not as discriminative as that of nuclear DNA (nucDNA), because it is inherited solely from mothers it can make no distinction between individuals of the same maternal ancestry. However, there are some advantages to mtDNA. Whereas each cell has at most one copy of its nucDNA, some cells can have 100-10,000 mitochondria, each with its own set of mtDNA. Because of this most tissue samples yield much more mtDNA than nucDNA. MtDNA is also found in some tissues which contain no nucDNA such as hair-shafts, bone, and teeth, and because the signal is

typically much more robust than nucDNA, it can often be recovered from very old and or very degraded tissue samples, which has made mtDNA very useful in solving cold cases (Sandhyarani, 2010).

Collection, Storage, and Transport of DNA Evidence

While DNA has the advantage of being the most discriminative form of forensic evidence, it also has the disadvantage of being the most susceptible to contamination and degradation. The most consequential form of contamination, which can invalidate a piece of evidence or lead to false accusations, is having a sample of evidence with DNA from multiple persons. The most likely causes of this are residue from multiple persons mixed by happenstance at the crime scene prior to collection, the mixing of evidence samples in the same container after collection, the collection of evidence samples with unclean tools used to gather other samples, or an investigator accidentally contaminating evidence with his own DNA (Schiro, n.d.).

The most likely causes of degradation of DNA evidence are the growth of microorganisms in improperly stored samples, and samples stored warm for extended time periods. Degradation may render DNA suitable only for PCR based analysis, as these methods rely on shorter lengths of DNA. Only the most severe degradation such as that found in tissues stored in formaldehyde can render DNA completely unsuitable for analysis (DNA.Gov). Microbial contamination is largely a degradation and not a contamination concern because microbial DNA would not be confused with human DNA during analysis (Federal Judicial Center, 2000, pg. 514). Luminol, often used to at crime scenes to detect latent bodily fluid stains, has been shown not to interfere with DNA analysis (Gross, 1999).

The following list is a general outline of the best manner to collect and store various forms of DNA evidence with the goal of preventing contamination and degradation.

Collection (FBI, 2007):

•Investigators should wear gloves during evidence collection.

•All tools and containers should be cleaned with water; bleach is unnecessary as it may damage biological evidence (Spear, n.d.).

•Liquid bodily fluid stains (blood, semen, saliva urine) should be absorbed onto clean cotton cloth and air dried.

•Small items with dried bodily fluid stains should be taken intact if possible.

•Dried stains on large objects should be excised if possible along with a reference sample of the object.

•Dried stains, which cannot be excised, should be absorbed onto clean cotton which has been moistened with distilled water and then air dried.

•Reference blood samples from involved subjects should be collected by qualified persons into tubes containing EDTA.

•Reference buccal swabs from involved subjects should be collected on clean cotton swabs and air dried.

Storage (FBI, 2007)

•Reference blood samples should be stored refrigerated, never frozen as this can rupture the tubes.

•Buccal swabs should be stored at room temperature

•Dried samples should be stored in clean paper or envelopes at room temperature.

•Dried samples should be frozen for long term storage.

•Samples should never be stored in plastic as condensation may promote microbial growth.

•Different pieces of evidence should never be collected or stored in the same container.

Chain of Custody

Webster's New World Law Dictionary defines chain of custody as "The order of places, where and the persons with whom physical evidence was located from the time it was collected

to its submission at trial" (Cain of Custody, 2010). The traceability of this chain of custody is a concern for all physical evidence, but even more so for DNA. The small amounts of DNA capable of linking a person with a crime scene also make DNA evidence susceptible to contamination, and necessitate that courts be able to trust the integrity of that evidence (DNA.Gov, n.d.).

Improvements and Advances in DNA Forensics

In the late 1980's, when the first court cases involving DNA evidence transpired, the most widely accepted standard for admissibility of scientific evidence was the *Frye Standard* from 1923 which accepted novel scientific techniques which had gained *general acceptance* in the relevant scientific community, and effectively deferred to those very experts. A later standard, Daubert from 1993, stated that novel scientific techniques not only have a general acceptance, but also be sufficiently *reliable* as determined by the court (O'Connor, 2006).

In the early years of cases involving DNA evidence, challenges to its admissibility were few. As the use of DNA evidence increased, so increased the challenges to it. However, the validity to the science behind DNA fingerprinting was largely upheld by the courts. The successful challenges were those that questioned the handling of evidence, laboratory techniques, data analysis and interpretation, and the performance and competence of laboratories (Calandro et al., 2005).

The first serious challenge to the admissibility of DNA evidence in the US was the case of *People of New York vs Castro, 1987*. In this landmark murder case, the court determined that the science behind DNA fingerprinting was sound and that the techniques used are capable of producing reliable results, but that in this particular case, laboratory procedures were not

performed properly (Kennesaw, n.d.). This case was instrumental in initiating a chain of events which has evolved into a collaboration between government agencies and private organizations to create *standards* and *guidelines* for DNA forensic work from the crime scene to the testing lab and DNA databases (Rudin and Inman, 2002). The creation of these standards and guidelines over the last two decades has been the principal improvement in DNA forensics making DNA evidence less dismissible by courts.

Improvements: Crime Scene Investigation

Most of what constituted proficient crime scene evidence collection prior to DNA fingerprinting still applies to the world of forensics in the age of DNA evidence. The improvements in the form of standards and guidelines is best illustrated by publications such as the FBI's *Handbook of Forensic Services* (cited earlier). Many such published reference manuals exist and are all in close agreement as to the best way to identify, collect, and store DNA evidence. There has also been a synergy between these types of guidelines and the commercial providers of supplies and tools for forensic DNA work which has served to enhance the standardization within the discipline.

Improvements: The DNA Lab

In 1988, following the recommendations of *People v Castro*, the FBI formed the Technical Working Group on DNA Analysis Methods (TWGDAM) from a number of private and public sector forensics experts in response to a lack of guidelines for quality assurance standards for DNA forensics testing labs. Revisions to its initial guidelines were issued in 1991, 1995, and 2004. The group was renamed the Scientific Working Group on DNA Analysis

Methods (SWGDAM) in 1999 (Calandro et al., 2005). These guidelines covered both testing laboratories, as well as the manufacturers of supplies and equipment. Congress granted no formal legal authority to TWGDAM, but its recommendations were to be considered the national standards until more formal ones were issued. Under the *DNA Identification Act* of 1994, a panel of distinguished forensic professionals known as the DNA Advisory Board (DAB) was created in 1995. Its initial mission was to create quality assurance standards for DNA testing laboratories, which were issued in 1998. The mission was expanded, and in 1999 the DAB issued quality assurance standards for DNA databasing laboratories (FBI, n.d.). When the DAB statutorily disbanded in 2000, the responsibility for updates and revisions to the guidelines and standards was returned to the SWGDAM.

Compliance with these standards requires an auditing process and an accreditation process. In 2004, the FBI issued a single standard audit form for DNA forensic labs and DNA databasing labs. In 2009, new and separate forms were issued for each type of laboratory. This audit addresses: QA programs, organization and management, personnel, facilities, evidence control, validation, equipment calibration and maintenance, reports, review, proficiency testing, corrective action, audits safety, and subcontractors (FBI, 2004). The primary accrediting organization of DNA laboratories is the American Society of Crime Lab Directors/Lab Accreditation Board (ASLCD/LAB), a private organization, which created a non-profit corporation, the National Forensic Science and Technology Center (NFSTC), which created a business division, Forensic Quality Services (FQS) that assists DNA forensics laboratories in gaining accreditation (Calandro et al., 2005).

These standards and guidelines effectively have influence because all forensics labs operated by the federal government which receive federal funding, or which participate in the

National DNA Index System (NDIS), must comply with the standards and receive accreditation (FBI, n.d.).

Chapter-2 Conclusion

Due to increases in the standardization of DNA analysis protocols mandated by early landmark DNA court cases, the technology has improved substantially. As the technologies further improve, the weight of attention will likely shift toward minimizing human error which will likely be the strongest variable for individual cases. So judges will decide on the admissibility of DNA evidence in pre-trial hearings for each case. The future is almost certain to bring new technologies and improvements to DNA forensics, and the quality assurance infrastructure developed over the last two decades, if vigilantly maintained, should continue to serve us well, guiding the discipline to better serve justice. Landmark DNA court cases, such as *People of New York vs Castro,* mentioned above, where the validity of DNA forensics was disputed, have been the impetus to improve field over the last two decades, and this case and others will be discussed in detail in the next chapter.

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Chapter-3: Landmark DNA Courtcases

Otilio DePina

As we saw in the previous chapters, DNA fingerprinting technology has proven to be a very powerful, reliable tool in science and criminal cases. However, US courts did not accept this science innovation right away. In this chapter we discuss several landmark court cases that set legal precedents for accepting complex technology, eventually including DNA fingerprints, in courts.

1923, Frye v. US

The first case to discuss, *Frye v. US,* is not a DNA fingerprinting case, but it was a pioneer case for using a scientific tool in a criminal trial. On November 25, 1920, a very renowned African-American physician was killed by a young man of the same ethnicity named James Frye. Even though there was an eyewitness, no suspects were identified until several months later when Frye was caught after committing an armed robbery. He confessed to committing both the armed robbery and the murder of Doctor Brown. But later, Frye negated the confession, claiming he and his friend were merely trying to get the reward money offered to help find Dr. Brown's murderer. To help Frye with his case, his attorney brought in an expert, William Marston, to conduct a new lie detector test. Marston described his test:

> "The test is described as a systolic blood pressure deception test. It is asserted that blood pressure is influenced by a change in the emotions of the witness, and that the systolic blood pressure rises are brought about by nervous impulses sent to the sympathetic branch of the autonomic nervous system. Scientific experiments, it is claimed, have demonstrated that fear, rage, and pain, always produce a rise of systolic blood pressure, and that conscious deception or falsehood, concealment of facts, or guilt of crime, accompanied by fear of detection when the person is under examination, raises the systolic blood pressure

> in a curve, which corresponds exactly to the struggle going on in the subject's mind, between fear and attempted control of that fear, as the examination touches the vital points in respect of which he is attempting to deceive the examiner". (Frye v US, 1923)

The lie detector test was conducted, and the result was in favor of Frye's innocence. But Judge McCoy objected to the use of the test, and did not even allow Marston to demonstrate the test to the jury. Based on the original confession, and other evidence, the jurors convicted Frye of second degree murder and a life sentence. Three years later, Richard Mattingly appealed to the Circuit Court of Appeals in the District of Columbia for Frye to receive a second trial on the basis that the lie detector evidence was not allowed. Appellate Judge Van Orsdel in a famous pre-trial hearing did not accept the lie detector test, as he believed it was still in its begging stages, and it needed to gain *general acceptance* among professionals in the field (in this case medical professionals). This general acceptance test eventually became known as the *Frye Standard*, used for decades in US courts for accepting new types of evidence (Fisher, 2008). The *Frye Standard* also addressed the use of expert witnesses:

> "The opinions of experts or skilled witnesses are admissible as evidence in those cases in which the matter of inquiry is such that inexperienced persons are unlikely to prove capable of forming a correct judgment upon it, for the reason that the subject matter so far partakes of a science, art, or trade as to require a previous habit or experience or study in it, in order to acquire a knowledge of it. When the question involved does not lie within the range of common experience or common knowledge, but requires special experience or special knowledge, then the opinions of witnesses skilled in that particular science, art, or trade to which the question relates are admissible in evidence" (Frye v. US, 1923).

The expert testimonies would be used only when really necessary, and the scientific tool would be used only when it has gained some recognition among the appropriate scientific community. But over the years, the *Frye Standard* of general acceptance became somewhat hard

to prove in court, so eventually in 1975 new *Federal Rules of Evidence 702 (Rule 702)* were enacted to ease the *Frye Standard*. The new rule stated that:

> "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence of 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 sufficiently based upon *reliable* facts or data. (2) the testimony is the product of *reliable* principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case (Federal Ruling, 1975)".

Rule 702 was applied in the following discussed case, but we will also see that the *Frye Standard* still had a great influence in the court room for more than half a century, as subsequent cases used the standard as parts of their three and five prong tests.

1992, Daubert, v. Merrel Dow Pharmaceuticals, Inc.

Jason Daubert was born with serious birth defects, and his parents, together with the Schuller family whose son also had birth defects , filed a law suit against Merrel Dow Pharmaceuticals, Inc, stating that the birth defects of both Jason Daubert and Eric Schuller resulted from their mother's ingesting Bendectin for antinausea during pregnancy. However, the defendant stated that its product does not cause birth defects, citing Dr. Lamm, who had published 30 studies involving more than 130,000 patients, concluding that Bendectin does not cause birth defects. Remaining unconvinced, the Daubert family brought in eight of their own experts who claimed that Bendectin indeed causes birth defects. Their conclusion was based on tests conducted on live animals, but the data was not peer reviewed. So the court found the plaintiff's evidence to not be admissible, stating it would only be admissible if it had been "sufficiently established to have *general acceptance* in the field to which it belongs" (Daubert, 1992).

However, the plaintiffs (who wanted their unpublished data accepted) argued that the *Frye Standard* was no longer in effect *Rule 702* should apply. But *Rule 702* with its reliability standard did not pertain to this case, so a new standard was drafted by the Judge, referred to as the *Daubert Standard.* It consists of three key provisions. First, the scientific knowledge must be grounded. Second, the knowledge must *assist* the trier of fact in understanding the evidence. Third, it states that the judge will determine whether the knowledge would assist the trier of fact. The *Daubert Standard* requires the judge to perform a preliminary assessment of whether the methodology underlying the testimony is scientifically valid, and whether that reasoning…can actually be applied to the facts (Daubert, 2010).

1986, Colin Pitchfork

This is a landmark case in which DNA fingerprinting technology was first applied to a murder case (Autopsy, 2004). It all started with the murder of two young girls of age fifteen in Narborough, United Kingdom, known to be a very quiet city. For both murders, the police found samples of semen, but initially had no suspect. So the police called in Alex Jeffreys who had invented DNA fingerprinting (Jeffreys et al., 1985) and who had already applied the new technology to solving a paternity case. Jeffreys' analysis showed that the semen from both murder cases belonged to one man. Later, the police caught a suspect, John Buckland, who confessed to having committed one of the crimes, but not both. When his DNA was tested, it did not match either murder case, so he was not the perpetrator, and this case became the first *exoneration* of an innocent individual using DNA testing.

Starting over on the murder case, the police started a big man hunt, testing all male subjects in the area by DNA testing. But none of the tested individuals matched the crime scene

DNA, and again police were left with no suspect. Eventually someone overheard a man in a pub, Colin Pitchfork, brag about paying someone else to give his blood sample, so he reported it to the police. The police obtained Pitchfork's DNA. Pitchfork confessed to doing both murders, and his DNA later proved the point. So this case became the first case in which a person was *convicted* of murder by DNA testing.

The Pitchfork case opened the door for DNA fingerprint technology to be used in many other criminal cases (Autopsy, 2004). Police found a new way to track rapists, murderers, and other criminals. Also, DNA fingerprinting has since been used to set many innocent people free, with John Buckland being the first. However, having DNA fingerprinting evidence is not enough to convict a criminal if the evidence is not analyzed correctly. The next landmark case addresses procedures for how to handle this precious evidence.

1989, People v. Castro

This is a case of the murder of Vilma Ponce and her two year old daughter allegedly by a Hispanic male, Jose Castro. While conducting the investigation, police saw a bloodstain on Jose Castro's watch during his interrogation. The blood evidence was sent to Lifecodes Inc. (Valhalla) for DNA testing, and the blood DNA profile was found to match the victims' blood. The prosecution attempted to enter the results into court, but the defense argued it was not performed correctly and should be disallowed. This case became the battle ground for establishing the validity of DNA testing. The case was heard by Judge Scheindlin, who established a new three-prong test for DNA evidence:

Prong I: Is the technology based on a theory that is generally accepted in the scientific community.
Prong II: Are the techniques capable of producing reliable results.

Prong III: Were the tests performed with techniques that are found to be accepted by the scientific community. (Patton, 1990)

Based on the new three-prong *Castro Test*, DNA testing was found to satisfy prongs 1 and 2, in general. But it failed prong-3, the specific evidence in this particular case was found not to be admissible because Lifecodes did not use approved procedures when conducting the test. So the DNA evidence was not allowed in court. The case never went to trial, as Castro later admitted to committing the murders. This case set a strong precedent on how DNA fingerprint evidence would be accepted in a court room, finally recognizing that the technology met the *Frye Standard* of general acceptance in theory, but adding in the critical third prong to ensure the testing was done accurately (Patton 1990). Another important outcome of the Castro case, was the judge's conclusion that the technology needed to be *standardized*, so the case resulted in the establishment of the Technical Working Group for DNA Methodology (TWGDAM) who developed the standard protocols used in numerous trials thereafter.

1991, People v. Miles

A female was sexual assaulted in her home, and the assailant forced her to go to the bank with him and withdraw money from her account. After threatening her life many times, the assailant fled leaving her in her car. The victim did not recognize her assailant, but the teller from the bank saw his face. Later, the police went to crime scene and collected traditional fingerprints and seminal stains from the victims bed sheet. Based on the bank teller's description, the police arrested Reggie Miles, who denied any involvement with the house robbery. But after his DNA test was found to match the crime scene evidence, he was convicted of three felonies: armed robbery, home invasion, and aggravated criminal assault.

This case did not involve the thorough examination of DNA evidence admissibility like *People v. Castro*. In this case the DNA testing was found to be done correctly. No evidence was presented showing DNA testing to be unreliable. The expert witnesses in this case were well-prepared. Although the defense counsel vigorously cross-examined each witness, the DNA testing by Cellmark was found to be properly controlled and performed by acceptable TWGDAM-approved protocols. So this case finally cemented the strong role of DNA testing in helping solve crimes when the test is performed correctly. Given these facts, the trial court properly admitted the DNA evidence, and Miles was convicted (People v. Miles, 1991).

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CHAPTER-4: SENSATIONAL DNA CASES

Adam Przystas

Introduction

Each of the landmark trials discussed in the previous chapter set legal precedents for entering complex technology into US courts, but the trials themselves are likely not familiar to most people. The purpose of this chapter is to remind the reader of a few sensational trials you are already familiar with, while focusing on the role DNA fingerprinting had in the trial as a reminder of the power of DNA technology. Many court cases have been sensationalized by the media which involved the use of DNA fingerprinting, but in this chapter we will focus on three such cases, taking a look at the case itself while focusing on the way DNA played a role in the case. Unlike Chapter-3 on landmark court cases, these cases may not have changed the way the legal system uses or views DNA evidence, each case shows how DNA can be extremely useful.

The OJ Simpson Trial

The first trial discussed in this Chapter, and probably the trial most people are familiar with, is the trial of Orenthal James Simpson for the murder of his ex-wife, Nicole Brown Simpson, and a friend of hers Ronald Goldman. The case was so sensational that even foreign leaders such as Margaret Thatcher and Boris Yeltsin followed the events and gossiped about the trial (Linder, 2003).

Ron Goldman was a waiter at an up-scale restaurant near where Nicole Simpson lived. On the night of June 12th 1994 at about 9:30 at night, Nicole called the restaurant where he

worked in order to find a pair of glasses which her mother had apparently lost there that night. Ron agreed to deliver the glasses to Nicole and they were put in an envelope for him to deliver. It is believed he went to his apartment to change from his waiter's uniform before bringing the glasses to Nicole (Wagner, 1999).

Nicole Simpson had been married to OJ Simpson in the 1970's and was the mother of his two children. She sought out Simpson after high school and eventually married him near the end of his football career and into his new life as a spokesman for several products. Together they lived in an estate also in Brentwood about two miles from the crimescene. The reasons for the divorce of the two are still unclear. The media hinted that Nicole felt deprived of the sexual experimentation most young people experience after high school, and that OJ could not see himself in a relationship with a wife so engaged (Wagner, 1999). However during the trial it was portrayed that she left because of physical abuse towards her, including a 1989 incident where he beat her severely and was ordered into therapy. Whatever the cause, Nicole filed for divorce in February 1992, though the two apparently continued to be friends over the years.

In December of 1993, Nicole moved into a condominium at 875 South Bundy Drive. She had suddenly decided to sell this house in the week or two before the crimes. She wanted to avoid taxes on the sale by saying she was moving back to the residence in Rockingham with OJ, however he would not agree to the ruse. In a note Nicole wrote to OJ in May 1994 she hinted at some unspecified danger in the air which came from a source other than him.

The day of the murders, OJ had just returned to Los Angeles to attend a dance recital his children were in and to attend a benefit the night before. He had a red eye flight to Chicago that same night at 11:45pm from LAX. A limousine was scheduled to pick him up at Rockingham at 10:45pm that night at Rockingham. The limo arrived at OJ's at about 10:23 for the 10:45 pickup

and parked near one of the front gates. At 10:40 the driver tried to raise someone in the house over the intercom to no avail. He tried until after 10:50, and then at around 10:55 saw a shadowy figure in dark clothing enter the house.

Just after midnight Nicole's howling Akita, with blood on its belly and legs, attracted the attention of a neighbor, who then discovered the two bodies (Linder, 2003). In a small area near the front of her house Nicole was found with a massive wound where her throat had been slashed, and Ronald Goldman was found nearby in the bushes. He had been stabbed about 30 times on the left side of his head and neck, and also suffered four deep stab wounds, one of which could have caused his immediate death.

Simpson was in Chicago when he finally heard of the murders on Monday and took the next flight back to LA. He was questioned by police that day, but the interview was completely inept and would end up not being used by either side in the trial to come. Most of the questions had to do with a cut on his right hand which was never answered satisfactorily. Police eventually found enough evidence that they filed a warrant for Simpson's arrest. The day after the funeral of Nicole, OJ led police on a low speed chase which eventually led to his arrest in his driveway at his home. This chase was televised and watched by millions of people.

The prosecution then made one of the biggest mistakes of the trial by filing the case in the downtown district rather than in the district where the crime occurred, which would have been normal procedure (Linder, 2003). More than likely this was a political move based on concerns that a conviction in Santa Monica with a predominantly white jury could lead to riots.

The trial itself began on January 24, 1995, and ended on October 3, 1995. It became the longest running court case in California history, including 150 witnesses over 133 days, and costing $15 million. The things which invariably led to the decision by the jury included the

painting of Mark Fuhrman, the LAPD officer who found a bloody glove at Simpson's house, as a racist who could have, and did in the past, plant evidence. This combined with the bad idea to have OJ try on a bloody glove which could have shrunk from blood on it helped to turn the jury in Simpson's favor. The final nail in the coffin of the prosecution's case however was Henry Lee, a Chinese-American forensic expert with solid credentials who poured doubt onto the prosecution's physical evidence. It took the jury only three hours to come back with a verdict of not guilty for the two murders.

Although no appeal happened in the criminal case after OJ was found not guilty, a civil case was soon filed in Santa Monica. The civil case would take just three months and produce a completely different result. After seventeen hours of deliberation, the jury found that OJ Simpson had wrongfully caused the deaths of Nicole Brown Simpson and Ronald Goldman, and ordered Simpson to pay compensatory damages of 8.5 million and punitive damages of $25 million.

Simpson Trial DNA Evidence

The OJ Simpson trial was remarkable not only for the amount of media attention it garnered but also because of the amount of DNA evidence presented in the case. The sheer amount of blood samples collected initially seemed to be rather damning for Simpson, however the defense team was able to put doubt into the jury through means of the supposed planting of evidence, and contamination of the samples gathered.

A large quantity of blood was found at the Bundy estate, and a trail of blood was found leading from the scene, as well as in Simpson's white Bronco and at his house (Wang, 2001). DNA fingerprinting was used to determine if the blood found at each scene belonged to either of

the victims or to Simpson. Blood from Brown's condo had DNA which matched Simpson. Blood spots from Simpson's bronco matched Brown, Goldman, and Simpson. At Nicole's house, the rear gate and walkway contained Simpson's blood (Wang, 2001). The socks found at OJ's had Nicole's and his blood on them. The glove found on his property also contained blood from all three of them.

There were five blood drops at Brown's home containing DNA that matched Simpson's, four were located on the walkway, and one was found in the driveway. The location of the drops indicates they were shed by the killer who was bleeding drops to the ground as he left the scene. The DNA analysis on the drops was done by the LAPD lab, by Cellmark (a private lab in Maryland), and by the California Department of Justice Lab (Wang, 2001). All three labs found that the DNA in the drops matched Simpson. An RFLP type analysis (discussed in Chapter-1) was performed on a drop from the driveway which was large enough for the procedure. This produced a 1 in 170 million match of Simpson's DNA to the DNA in the driveway. The other four drops were tested with the more sensitive PCR testing.

These five drops of blood were among the most powerful evidence against Simpson because unlike other samples these were collected *before* the LAPD had a sample of Simpson's blood. This meant that any potential police tampering would have involved not simply planting evidence but substituting it. It was also argued that the samples could have been contaminated when in the lab. LAPD criminalist Collin Yamauchi admitted that he spilled some of Simpson's blood from a reference vial while working in the evidence processing room, and that shortly thereafter he handled the Rockingham glove and the cotton swatches containing the blood from the Bundy drops (Thompson, 2008). The defense proposed that some of Simpson's blood was transferred to this evidence, although they provided no evidence this transfer actually occurred. It

was also shown by the defense that the blood on Simpson's sock could have been planted, because detectives had the blood samples needed to place this evidence, although again no evidence was provided for this potential planting. The last major question that arose was if the blood drops found on the walkway and driveway at the Bundy estate had been contaminated with DNA by a lab error, they would not only have shown Simpson's DNA profile but also that of the real killer as well (Wang, 2001), but only Simpson's profile was present. In the end, although no evidence was provided by the defense that blood transfer or planting actually occurred, in the juror's eyes it remained a *possibility*, so the prosecution did not make their case "beyond a resonable doubt". The subsequent civil trial where he was found guilty functioned by the lesser standards of "preponderance of the evidence".

The Boston Strangler

The Boston Strangler was a serial killer responsible for killing 11-12 single women in the Boston area between June 14, 1962 and January 4, 1964. At least eleven of these murders were commonly believed to be victims of the Boston Strangler, while the other two victims had slightly different *modus operandi*. While police did not see all of these murders as the work of a single individual, the public did (Bardsley and Bell, 2003). All of the women were murdered in their apartments, had been sexually molested, and were strangled with articles of clothing. In each case, there were no signs of forced entry, and it was assumed the women either knew their assailant or let him in voluntarily.

The first victim of the strangler was 55 year old Anna Slesers, a petite divorcee who looked years younger than her age. She lived at 77 Gainsborough Street in a small apartment designed to meet the needs of students or retired people with limited incomes. Anna was a

seamstress making $60 a week, and lived on the third floor of the apartments. The first attack occurred on June 14, 1962, after Anna had finished dinner and was trying to get in a bath before her son picked her up at 7pm. When he arrived just before 7:00, he received no answer to his knocks and the door was locked. When he finally broke in the door he found his mother's body on the bathroom floor with the cord from her robe around her neck. She had been sexually assaulted with an unknown object before being strangled with her robe. The cord was tied tightly in a bow under her neck. Her apartment had been made to look like it had been ransacked, but no valuables had been taken.

The second murder took place on June 30 when sixty-eight-year-old Nina Nichols was found murdered in her apartment at 1940 Commonwealth Avenue in the Brighton area of Boston. Again, the apartment looked like it had been burglarized, with objects strewn all over the apartment. Once again, none of the valuables in the house had been taken. She was found with her housecoat and slip pulled up to her waist and had been sexually assaulted. Her own nylon stockings were tied tightly around her neck, with the ends tied in a bow. Her time of death was believed to be around 5pm. Just like Anna, she had led a quiet life and had no male friends except for a brother-in-law.

On the same day as Nina Nichols murder, the third murder occurred fifteen miles north of Boston in the suburb of Lynn. Helen Blake was killed sometime between 8 and 10am. She was found nude lying face down on her bed with legs spread apart, and she had been sexually assaulted. The sixty-five-year-old divorcee had been strangled with one of her nylons, and had her brassiere looped around her neck and tied in a bow. Her apartment had also been ransacked, and it appeared as though two of her rings were missing.

After these murders, police commissioner Edmund McNamara was very alarmed and sent a warning to all women in the Boston area to lock their doors and be wary of strangers. McNamara cancelled all police vacations, and transferred all detectives to work for homicide (Bardsley and Bell, 2003). McNamara also called the FBI to hold a seminar on sex crimes for his fifty best detectives. The police were looking for a madman, one that probably attacked older women because of some hatred for his mother.

On August 19, the fourth victim, seventy-five-year-old Ida Irga fell victim to the strangler. She was found two days later in her apartment at 7 Grove Avenue in Boston's West End. She was found lying on the living room floor with a torn nightdress which completely exposed her. There was a white pillowcase knotted tightly around her neck. She had also been sexually tampered with, although no spermatozoa were present. She had died from manual strangulation but most of the details of how she was found were withheld from the press.

Jane Sullivan a sixty-seven-year-old nurse was the strangler's fifth victim. She was killed within twenty-four hours of Ida Irga's murder. Jane was killed in her apartment at 435 Columbia Road in Dorchester, across town from where Ida lived. She had been dead for about ten days before she was found. Police found her on her knees in the bathtub with her head under the faucet with her feet over the back of the tub. She had also been strangled with her own nylons probably in a different room where blood was found on the floor. She may have been sexually assaulted, but the body was so badly decomposed it could not be determined. There was no sign of forced entry, and the apartment had not been ransacked.

Panic started to grip Boston, but luckily the city got a 3 month period of inactivity, and police were able to check out everyone they wanted to check out, such as known sexual

predators. But nothing much came of this flurry of activity except the creation of a long list of people who were probably not the strangler (Bardsley and Bell, 2003).

On December 5, 1962, the brief reprieve ended with the murder of the sixth victim, Sophie Clark, a 21 year old African-American student at the Carnegie Institute of Medical Technology. The apartment she shared was at 315 Huntington Avenue, a couple of blocks away from Anna Sleser's apartment. Sophie was found nude in the living room of her apartment strangled by three of her own nylon stockings, and her half slip had also been tied around her neck. The apartment had been rummaged through and there were signs of sexual assault, semen was found near the body. The differences between this case and the earlier ones were evident, Sophie was young and black, and she did not live alone. This was also the first time semen had been found at the crimescene.

Patricia Bissette was the seventh victim of the strangler three weeks after Sophie. She was discovered on Monday, December 31, 1962 when her boss became worried about her. She lived at 515 Park Drive, and was found face up in bed with the covers drawn up to her chin. Underneath the covers several stockings and a blouse were tied tightly around her neck (Bardsley and Bell, 2003). There was evidence of recent sexual activity and her apartment had been searched.

A couple of months went by until the eighth murder. On March of 1963, sixty-eight-year-old Mary Brown was found beaten to death in her apartment. She was found twenty-five miles north of Boston in Lawrence, and had also been strangled and raped.

On Wednesday May 3, 1963, Beverly Samans, a twenty-three-year-old graduate student, was found murdered in her apartment, the ninth victim. She was found on a sofa bed with her legs spread apart. Her hands had been tied behind her and a nylon stocking and two

handkerchiefs were tied around her neck. However, she had not been strangled, she had been stabbed twenty-two times, and had also not been raped.

Three months passed until the tenth murder on September 8, 1963. Evelyn Corbin was found in Salem; she was fifty-eight-years-old but passed herself off as much younger. She lay across her bed face up and nude, and had been strangled by two of her nylon stockings. Spermatozoa were found at the scene and her apartment had been searched.

On November 25, the eleventh victim, Joann Graff was raped and murdered in her Lawrence apartment. The twenty-three-year-old was found with two nylon stockings tied in an elaborate bow around her neck.

The 12th murder happened on January 4, 1964, at 44A Charles Street. Nineteen-year-old Mary Sullivan was found by her two roommates. She had been strangled with a dark stocking over which two scarves were tied. She was propped up against the headboard of her bed and had been sexually violated.

After this murder the case was taken over by Edward Brooke, the Massachusetts Attorney General. He decided to put together a team to coordinate all evidence over the five police jurisdictions the cases had occurred. The task force was headed by Assistant Attorney General John S. Bottomly. Two months later, the governor offered a $10,000 reward to anyone who furnished information leading to the arrest of the strangler. The forensic medical experts for the team saw important *differences* between the murders of the older women and the younger women, and for this reason they thought it unlikely one person was responsible for all the murders.

In November of 1964, the police arrested Albert Desalvo, a thirty-three--year-old man in connection with a case unconnected with the strangler. Desalvo had been arrested before for

strange sexual offenses in 1961, and was released in April of 1962, two months before the first strangler victim was found. Desalvo was found to be The Green Man, a sexual assailant police were looking for in Connecticut who commonly wore green pants. On October 27 of 1964, he had broken into an apartment and assaulted a woman who got a good look at his face. He subsequently admitted to breaking into four hundred apartments and committing a few rapes.

Desalvo was sent to Bridgewater State Hospital for observation. While there he met another inmate in the same ward named George Nassar who became his confidant. Albert apparently started thinking of money for his family and how to get it while being jailed the rest of his life. He told his lawyer that he was the strangler, and he began to look into it. Desalvo intended to convince everyone he was insane. Nassar said he would turn Desalvo in, Desalvo would confess, and they would collect the reward money from the governor. F. Lee Bailey was Nassar's lawyer, and heard about Desalvo and decided to take his case. Albert confessed to him of the murders of the eleven "official" victims and also to the murder of two other women.

Bailey then started to question Desalvo to make sure he was really the strangler. He asked Albert questions which would help prove if it was really him. Desalvo answered them all with great detail that lead Bailey to believe he was the strangler. The police then had to check every detail of his confessions. On September 29, 1965, the interrogation was complete. They ended up with more than 50 hours of tape and 2,000 pages of transcription. The police's original doubts about whether Desalvo was the strangler were dissipating. The Strangler Bureau eventually decided Desalvo was the Boston Strangler.

Before he could be tried as the strangler, Desalvo was tried for the Green Man crimes and eventually was found guilty, receiving life in prison. Albert Desalvo was serving his life sentence at Walpole State Prison when he was stabbed to death in the infirmary in November of 1973. The

night before he was stabbed, he had called and asked Dr. Robey, the psychiatrist from his time at Bridgewater State, to meet him the next day with a reporter, however nobody knows what he was going to tell them. Because of Desalvo's death, nobody has ever officially stood trial for the Strangler murders.

Many people even today do not believe Desalvo was true strangler. None of his family, co-workers, and even the police who knew him from his previous arrests thought him capable of the killings. Also no physical evidence was ever found to link him with any of the crimes. The police also had found cigarette butts at several of the crime scenes but Albert did not smoke. Also, none of the eye-witnesses said that Desalvo matched who they had seen, and Albert's face was very memorable. Susan Kelly, author of *The Boston Stranglers,* believes that Desalvo fabricated the entire story (Wuebben, 2001). She says he knew many case details, but that newspapers were a great source of information, and the things he got wrong were the same as in the papers.

The Boston Strangler DNA Evidence

DNA fingerprinting technology was not available when the strangler murders took place in 1963-64, however decades later several people are trying to look back into the case. Diane Dodd, the sister of victim Mary Sullivan, and Albert Desalvo's brother Richard who believes Desalvo is not the strangler, are pushing the state to reopen the case (Wuebben, 2001). Diane Dodd allowed Sullivan's body to be exhumed in the hopes that more evidence, including DNA evidence, could be found. Although Sullivan's body had deteriorated, forensics expert James Starrs was able to extract several pieces of interesting evidence. Professor Starrs said an examination of the DNA profile of a semen-like substance on her body did not match Desalvo's

DNA (BBC News, 2001). And forensic analysis of DNA found on Mary Sullivan's underwear and pubic hair belonged to neither her nor to Desalvo. This evidence by itself does not exonerate Desalvo, but combined with the earlier police testimony and eyewitness accounts, it now viewed that Desalvo was likely not the murderer of Mary Sullivan. It is hoped that this interesting evidence will now lead to Massachusetts reopening the case and allowing forensic experts to analyze evidence collected from the other victims, although some family members appear to be resisting the reopening of the graves and the bad memories the strangler case brings.

The Grim Sleeper

The Grim Sleeper is a serial killer who had been operating in the south Los Angeles area for over two decades. Linked to the deaths of at least 10 women starting in the mid 1980s and another set more recently, the unknown killer was dubbed the Grim Sleeper due his long period of inactivity between one set of his killings and the other (Sher et al., 2010).

The first victim of the Sleeper was Debra Jackson, a 29 year-old cocktail waitress and prostitute, who was found on the 10th of August 1985 in an alleyway in West Gage Avenue/South Block Avenue. She had been shot twice in the chest with a .25 handgun, and her body was hidden under an old carpet. She had been sexually assaulted, but was fully clothed when found (The Grim Sleeper Investigation, 2010).

The second killing was not until August 12, 1986, in the 2500 block of West Vernon Avenue. Henrietta Wright, 35, was found wrapped in a blanket which was then covered by a mattress. She had also been sexually assaulted and then shot twice in the chest by a .25 handgun. She was found fully clothed but her shoes were missing.

On August 14, 1986, Thomas Steele was found shot once behind his right ear. He had been dumped in the road fully clothed near 71st Street and Halldale Avenue. Steele is the only male victim of the Grim Sleeper and was not assaulted. It is still unclear why he was targeted by the Sleeper. The ballistics for the .25 caliber gun used matched the other victims however.

Barbara Ware, 23, was found January 10, 1987, in an alley in the 1300 block of East 56th Street (The Grim Sleeper Investigation, 2010). She had been shot once in the chest with a .25 caliber weapon, and was dumped fully clothed with a plastic bag over her upper torso and head. She had also been sexually assaulted, and was rumored to be a prostitute. An anonymous caller to 911 had reported seeing a blue and white van dump a body in an alleyway. It is believed this was Barbara Ware's body but the caller was never found.

The next victim was Bernita Sparks, who was 25, she was found on April 16, 1987, in an alley in the 9400 block of South Western Avenue. She had been shot in the chest once with a .25 caliber weapon, but also had signs of strangulation and blunt-force trauma. She was found inside a trash bin covered with trash but fully clothed. Sexual assault was also evident.

On October 31, 1987, Mary Lowe told her mother she was going to a Halloween party. Lowe was found the next morning in an alley near bushes behind the 8900 block of Western Avenue. A neighbor said they saw Mary Lowe get into a car with a young black man driving a rust or orange Ford Pinto (TimeRime, 2010).

The next victim was Lachrica Jefferson, a 22 year-old who was found on January 30, 1988, in an alley in the 2000 block of West 102nd Street in Lennox. She had been shot twice in the chest, again with a .25 handgun. As with all the female victims she had been sexually assaulted. Her body had been covered in a mattress, and a napkin had been placed over her face with the word "AIDS" written on it.

Alicia Alexander was found in an alley in the 1700 block of West 43rd Street and Western Avenue. She was 18 when found on September 11, 1988. She was found nude and had been shot once in the chest. Her body was covered with a mattress and had been sexually assaulted.

Enietra Margette was 29 when she was attacked on November 20, 1988, by a black man aged around 30. The attack occurred in south Los Angeles. She was shot in the chest, and sexually assaulted then left for dead. She survived is the only known eye-witness of the Sleeper. She also said that her attacker was driving a Ford Pinto and the bullet removed from her chest matched the gun used to kill the first eight victims.

After this 1988 attack, with a surviving witness, it appears the Grim Sleeper stopped all attacks for the next 14 years. In 2001, the then current police chief Bernard Parks instructed detectives to re-examine cold case files using new DNA technologies (The Grim Sleeper Investigation, 2010). This resulted in links between several cases ultimately attributed to the Grim Sleeper.

Then on March 9, 2002, Princess Berthomieux was found in an alley in the 8100 block of South Van Ness Avenue in Inglewood. The new victim was only 14 and the youngest of the Sleeper's victims. She had not been shot, but had been strangled and was linked to the other murders through DNA evidence.

Valerie McCorvey, 35, was found July 11, 2003, between 109th and 108th Streets near Denker Avenue. She had been strangled to death and dumped in an alley. She had also been sexually assaulted like the other victims.

In 2005, an LAPD detective Cliff Shepherd found a match between Valerie McCorvey, Princess Berthomieux, and a preserved DNA sample taken from Mary Lowe in 1987

(TimeRime, 2010). This find links the earlier murders with the two more recent stranglings, marking them all the work of the Grim Sleeper.

On January 1st, 2007, Janecia Peters, 25, was found dead near 9500 Western Avenue. She had been shot in the back, and was dumped in a garbage bag. She had also been sexually assaulted, and was the last confirmed victim of the Grim Sleeper.

After the last murder in 2007, a $500,000 reward was offered for any information leading to the capture and arrest of the Grim Sleeper, the biggest reward ever offered in LA. However, no suspect was identified until the police found a partial (likely familial) match to Christopher Franklin in the criminal database. Believing Christopher might be the son of the Grim Sleeper, the police had his father tailed until they could get DNA evidence from a pizza container. The DNA profile from the pizza container matched the Grim Sleeper evidence, and the police finally arrested Lonnie D Franklin Jr. Lonnie Franklin has been charged with 10 counts of murder and one count of attempted murder. He is now in an LA jail awaiting trial.

The Grim Sleeper DNA Evidence

The DNA research which finally allowed the Grim Sleeper killings to be cracked is a relatively new method termed familial DNA. Since 2008, California has allowed so-called familial DNA searches, in which investigators look for close but not exact matches between DNA evidence collected at crime scenes and the state's databank of DNA profiles from 1.3 million convicted felons (Miller, 2010). This new method has a longer history in the UK where in 2004 it led to the first conviction in a murder case by familial matching.

Familial DNA uses short-tandem-repeats (STRs) (discussed in Chapter-1) to generate a ranked list of felons who are most likely to be first-order relatives (parents, children, or full

siblings) of the person a DNA sample came from. The statistics are not strong enough to identify more distant relatives with only a quarter or less of DNA shared between them. When both people in question are male, scientists can also look at a number of STRs on the Y chromosome, which should be an exact match between fathers and sons, and between full brothers.

A 2008 database search using DNA from the Grim Sleeper crimescenes came up empty. However a second familial DNA search conducted in April 2010 turned up Christopher Franklin who was in the database from a 2009 conviction on a felony weapons charge. The DNA search and the dates of the murders then moved suspicion to Franklin's father. The LA police were notified and followed the father Lonnie Franklin until they got a DNA sample from a discarded piece of pizza. Lonnie Franklin's DNA matched that found at the Grim Sleeper crimescenes and he was arrested.

This type of DNA testing has raised questions about potential race discrimination, since an overabundance of inmates (and thus DNA profiles) are African-American. It also raises issues of privacy and fairness, as relatives of criminals might be incorrectly incarcerated, so great care must be used with suspects identified by this new technique. Most people have a right to privacy, and this method disrupts that privacy if you are a relative of someone who committed a felony. All of this will need to be taken into consideration when using this new method in the future.

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Chapter-5: DNA Databases

Otilio DePina

It all began in 1985 with the Colin Pitchfork case, and the rape and murder of two teenage girls, where DNA fingerprinting was first used to solve a murder. Since then, the collection of DNA profiles from crimescenes and from convicted offenders has become extremely important for solving crimes, and DNA databases were developed to help manage this information. However, with the storage of DNA information comes worries about privacy rights. The purpose of this chapter is to discuss the purpose of DNA databases and their ethics.

The DNA Database

In 1990, the FBI launched a pilot project CODIS (Combined DNA Index System), an electronic database of DNA profiles that could identify suspects. This project initially involved twelve states and their local crime laboratories. Later in 1998, established by the DNA Identification Act of 1994, an amendment to the Omnibus Crime Control and Safe Street Act of 1968, CODIS went online to become the world's largest DNA database.

The *People v Castro* case of 1989 (discussed in Chapter-3) resulted in a request to standardize DNA testing methodologies, and this case resulted in the establishment of the Technical Working Group on DNA Analysis Methods (TWGDAM), also known as the Scientific Working Group on DNA Analysis Methods (SWGDM). TWGDAM helped standardize the technology for entering DNA profiles into CODIS to help ensure the DNA data collection and storage was properly done. The TWGDAM guidelines were used as interim to another standard later put in place on October 1, 1998, the *Quality Assurance Standards for Forensic DNA*

Testing Laboratories and the *Quality Assurance Standards for Convicted Offender DNA Databasing Laboratories* (Adams, 2002).

The DNA Identification Act of 1994 authorized the FBI to create and maintain a national DNA Index that would include information from people convicted of crimes, samples recovered from crime scenes, samples recovered from unidentified human remains, and samples voluntarily contributed by relatives of missing persons. Its access is limited to authorized users only. The FBI made CODIS their major priority. CODIS is kept in a secret location, and all the data are encrypted with a $100,000 fine on any unauthorized disclosure (Stevens, 2001). It is protected with administrative, physical, and technical safeguards.

In order to develop a national CODIS, each state was given the option to get involved by merging their state database with the FBI's (**Figure-1**). When a state links to national CODIS, the FBI provides them with software, training, and user support.

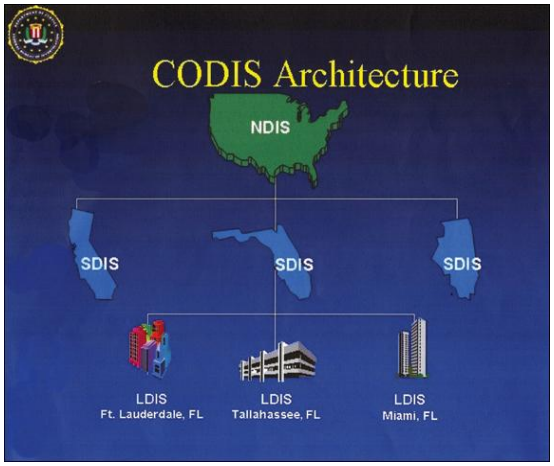

Figure 1: Diagram of CODIS Hierarchy. Note that local databases link to state databases that link to the national database. **(**FBI Publications)

CODIS software connects forensic laboratories throughout the United States allowing them to share and collect information to help solve crimes. As stated by Dwight E. Adams, the FBI's laboratory division assistant director during a congressional hearing:

> "One of the underlying concepts behind the development of CODIS was to create a database of a state's convicted offender profiles and use it to solve crimes for which there are no suspects. Historically, forensic examinations were performed by laboratories if evidence was available and there was a suspect in the case. By creating a database of the DNA profiles of convicted sex offenders and other violent criminals, forensic laboratories would be able to analyze those cases without suspects and search those DNA profiles against the database of convicted offenders and other crime scenes and determine if a serial or recidivist rapist or murderer was involved. It was expected that this new tool would enable forensic laboratories to generate investigative leads or identify suspects in cases, such as stranger sexual assaults where there may not be any suspects.
>
> The CODIS software is used to maintain these DNA databases and search the DNA profile against the DNA profiles of convicted offenders and other crime scenes. For example, a DNA profile of a suspected perpetrator is developed from the sexual assault evidence kit. If there is no suspect in the case or if the suspect's DNA profile does not match that of the evidence, the laboratory will search the DNA profile against the Convicted Offender Index. If there is a match in the Convicted Offender Index, the laboratory will obtain the identity of the suspected perpetrator. If there is no match in the Convicted Offender Index, the DNA profile is searched against the crime scene DNA profiles contained in the Forensic Index. If there is a match in the Forensic Index, the laboratory has linked two or more crimes together and the law enforcement agencies involved in the cases are able to pool the information obtained on each of the cases. Matches made by CODIS and confirmed by the participating laboratories are often referred to as CODIS "hits." "(Adams, 2002).

DNA Database Uses

DNA databases give law enforcement agencies the ability to find criminals even when there is no potential lead in the case. It especially helps solve cases for repeat offenders. For example:

> "A college professor was raped and murdered in Flint, Michigan in 1986. A search of the Michigan state fingerprint files was negative, and no suspects were developed in the case. Five years later, a flight attendant was raped and murdered

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

Figure-2 shows a chart with the types of cases CODIS has helped solve in Hamilton County, Cincinnati, Ohio. Note that the vast majority (72%) are rape cases, likely due to the increased reporting of this crime, and because semen contains high quantities of DNA.

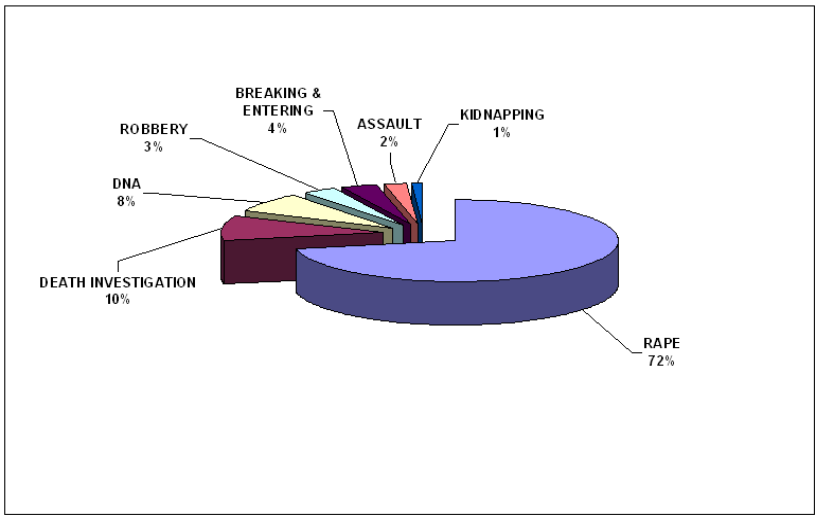

Figure 2: Types of Cases Solved by CODIS in Ohio. (Hamilton Country Coroner's Office: Annual Report, 2002)

Also it is important to use large DNA databases to help assign specific allele frequencies in the population. The larger the database, the more accurate scientists can determine the probabilities of a random match. Sequencing someone's DNA from the beginning to end has only been done a few times so far, and is too labor intensive to perform for crime scene samples. Instead for crime scene samples, specific 13 core loci are analyzed (discussed in Chapter-1). In

the United States, the standard for forensic identification requires a comparison of 13 DNA segments. Reliable identification requires that samples be handled carefully to prevent contamination, that a sufficient number of segments be compared, and that researchers set an appropriately high threshold for acceptable probability of a chance match. There have been cases and near-misses of mistaken DNA identification when one or more of these conditions were violated. For example, MSNBC reported that an identification mistake was avoided when the medical examiner insisted on a 99.99 percent certainty of non-random match for the remains of a firefighter who died in the aftermath of the attack on the World Trade Center on September 11, 2001. A sample appeared to match one of the firefighters with 90 percent probability, but additional work showed that at the 99.99 percent level there was actually a closer match with a different firefighter (Genetic Privacy, 2007).

DNA Databases: An Invasion of Privacy?

Some people consider the storage and use of someone's personal information as an invasion of the individual's privacy. "Hence any regulatory framework enabling the setup of a DNA database has to address the privacy issue and make a compelling case for using such a database" (Mayer-Schonberger, 2003).

Although most people focus on the benefits of DNA databases, some people like attorney Maya Harris, Director of ACLU of Northern California's Racial Justice Project, believe that putting your DNA sample in CODIS it is like opening your windows to your most private intimacy, such as predispositions to Alzheimer, depression and cancer. If you do not allow law enforcements in to your house without a proper warrant order, why would let them have your DNA samples, without you been charged of any crime (American Civil Liberties, 2004). For

some States like California for them to take DNA sample from you, you just have to be *arrested.* California also holds more than seven million infant blood samples, when babies undergo tests to determine their blood type for PKU, without parents' consent (Bereano, 2000).

Massachusetts authorizes any disclosure that may be required as a condition of federal funding, and permits the disclosure of personally identifiable information for advancing other humanitarian purposes. Nevada permits the sample to be used for analysis in to finding genetic markers of the blood. Since there is no definition on the "genetic markers" it could include information that could be derived from DNA. Also, there are no restrictions on the use of the original DNA sample (Steinhardt, 2003).

Since 1991, the U.S Department of Defense (DOD) has been taking DNA samples from all its personnel, for the purpose of identification if killed in action. Civilian personnel may have their samples in the DOD DNA bank. As of 2003, the United States military's DNA depository held 3.8 million samples. However, individuals have the right to request that their samples be destroyed when they end they service to Department of Defense.

There was particular case in which two United States Marines did not give their DNA samples, and they were charged with violation of an order from a superior commissioned officer. Their charge was dismissed by the court martial, holding that the regulation underlying the DNA Repository program were not punitive, therefore no disciplinary act was taken against them. They tried to sue the United States Government, saying that the DNA sample collection violates the fourth amendment, but the court found the DNA collection to be valid. The court found the case to be moot because those two Marines never gave the samples they were asked. Later, two members of military refused to give samples, but they were trial and sentenced (Genetic Privacy, 2007).

There has also been proven genetic discrimination in the health insurance community. Many cases have been documented about people denied employment or insurance based on their genetic predictions:

- "A pregnant woman, whose fetus tested positive for cystic fibrosis, was told by her health maintenance organization (HMO) that it would be willing to cover the cost of an abortion but would not cover the infant under the family's medical policy if she elected to carry the pregnancy to term.
- A healthy woman, who casually mentioned to her family doctor that her father had been diagnosed with Huntington's disease, and that she herself was at risk for inheriting this genetic disorder, was later denied disability insurance. The insurance company rejected her because they found a note about her father's diagnosis written in the margin of her medical records.
- A healthy boy, who carried a gene predisposing him to a heart disorder, was denied health coverage by his parents' insurance company, even though the boy took medication that eliminated his risk of heart disease.
- One healthy man in his 20s with a gene for the degenerative brain condition Huntington's disease was refused life insurance. His older brother, on the other hand, tested negative and was able to reduce his premium which had been previously set on a family history of the disease.
- Another case involved a well woman in her 30s whose genetic test indicated a 70 to 90 per cent risk of developing cancer. Despite having regular screening for cancer, her superannuation was reduced and the life cover component refused"

  (Bereano, 2000).

These cases described by Philip Bereano are now preventable with the new Health Care Bill H.R.3590 passed in March 23, 2010, which stops insurance companies from denying health insurance coverage for people with preexisting conditions. Therefore, it will be hard for insurance companies to be able to use your genetics information against you.

Nevertheless, people are still questioning whether not people can get information about you through a DNA database. The answer is negative. The information put in CODIS on the 13

core loci is just for identifying purposes. So people's fears about a hacker breaking into CODIS to retrieve medical predisposition information are misinformed, as CODIS contains no such information. However, the original biological sample taken by the law enforcement agency can "provide insights into most personal family relationships and the most intimate working of the human body" (Steinhardt, 2003). So in theory, the original DNA sample could be tested beyond the original 13 loci to possibly determine medical predispositions. But by destroying the original biological samples after collecting CODIS information, it would prevent people from attempting to misuse it.

However, some people think the original samples should not be destroyed, as they could be used later if new DNA matching techniques are discovered, or if there is problem with the original CODIS entry. On the other hand, some think, "One can always draw a fresh sample from the suspected individual and test it" (Mayer-Schoenberger, 2003).

Who Should Provide DNA Samples?

In the US, individual states determine who should provide samples to CODIS, and the states vary (**Figure-3**). Some states include only people convicted of *some* felonies, others enter everyone convicted of felony, and 21 states include some *arrestees*. However, all 50 states require DNA from convicted sex offenders. And at this time, 47 states require all *convicted* felons to provide DNA sample to the database. And, about 15 states include some misdemeanors among those who must provide DNA sample (National, 2010).

State	All Felonies	Some Juveniles	Some Misdemeanors	Some Arrestees	Not Guilty By Mental Defect or GBMI	Other
Alabama	X					
Alaska	X	X		X -- Violent felonies.		
Arizona	X	X		X -- Many serious felonies.		Includes residential and criminal burglary.
Arkansas	X	X -- Violent crimes only.	X -- Some sexual offenses.		X	
California	X	X		X -- Expansion to all felon arrestees starts in 2009.		Includes those convicted of terrorist activity in violation of weapons of mass destruction provisions; and those convicted of a qualifying offense in another state.
Colorado	X	X				Includes any person who has a duty to register as a sex offender, including probationers, habitual offenders as condition of parole, and those released without parole supervison.
Connecticut	X				X	Includes persons on probation or parole prior to discharge from supervision.
Delaware	X		X -- Certain child endangerment or abandonment crimes.			
Florida	X	X			X	Includes persons on probation, parole, release or supervision following conviction of certain offenses.
Georgia	X	X				Includes probationers convicted of qualifying offense.
Hawaii	X	X			X	Includes qualifying persons in prison, on probation or parole, parole violators.
Idaho		X				Most felons are included.
Illinois	X	X	X -- Any person required to register as a sex offender, includes some misdemeanors.			Includes people held under civil commitment law, those found guilty but mentally ill for a sex offense, persons seeking transfer to state under interstate compact, stalking and residential burglary.
Indiana	X					Includes qualifying offenders on probation or parole.
Iowa	X	X	X Any person required to register as a sex offender. Any criminal offenses against minors included.		X	Includes qualifying parolees and offenders on work release and offenders receiving a deferred judgment of felony.

Kansas	X	X		X -- Felony or drug grid level 1 or 2; expands after June 30, 2008 to include all persons arrested for a felony.		
Kentucky		X				Includes those convicted of unlawful transaction with a minor, promoting sexual performance of a minor, Burglary I and II and Class A and B felonies involving death or serious injury to the victim.
Louisiana	X	X		X --If funds authorized.		
Maine	X	X	(May include a lesser included offense if a qualifying offense was originally charged.)			Includes all Class A, B, C serious crimes and Class D and E convictions if the person had prior felony conviction for which DNA not collected.
Maryland	X	X	X	X -- Violent crimes, burglary and breaking and entering of a motor vehicle.		
Massachusetts	X	X				
Michigan	X	X		X -- Violent felonies.		
Minnesota	X	X	(May include offenses "arising out of same set of circumstances.")	X -- Specified serious crimes upon judicial finding of probable cause.		
Mississippi	X					
Missouri	X					
Montana	X	X				
Nebraska						
Nevada	X		X -- Failure to register as a convicted person.			
New Hampshire		X				Includes violent crimes.
New Jersey	X	X	X -- Any crime for which a sentence of imprisonment of 6 months or more is imposed.		X	
New Mexico	X	X		X -- Specific violent felonies.		
New York	X		X -- Many misdemeanors.			
North Carolina	X				X	Includes persons on community supervision.
North Dakota	X			X -- All felonies – effective 01/09.		Many serious felonies, including burglary.
Ohio	X	X	X -- Certain child victim offenses.			

Oklahoma	X					2001 law requires planning to incrementally add qualifying felonies to the database, to include all felony offenses by 2006.
Oregon	X	X				
Pennsylvania		X				Includes violent and sexual offenders.
Rhode Island	X					
South Carolina	X	X	(May be required by court order for any offense.)	X -- Violent felonies punishable by more than 5 years in prison.		Includes qualifying offenders on community supervision.
South Dakota	X	X		X -- Violent felonies punishable by more than 5 years in prison.		
Tennessee	X	X		X -- Violent felonies, upon finding of probable cause.		Includes those persons seeking transfer to the state under interstate compact who have committed qualifying offense.
Texas	X	X	(May be required by court order for any offense.)	X -- Post-indictment only in certain sex crimes.		Expanding to all felons contingent upon federal funds.
Utah	X	X	X -- Class A misdemeanors. Others may qualify if convicted on lower degree of qualifying offense.		X	Includes persons convicted in another state of a qualifying offense.
Vermont	X		(Only if as part of a plea agreement.)			
Virginia	X	X		X -- Violent felonies, including attempts.		
Washington	X	X				Includes those who have been convicted out of state or under federal law of a violent offense.
West Virginia	X					
Wisconsin	X	X	X -- Some misdemeanors for which sex offender registration is required.		X	
Wyoming	X	X				Includes all persons required to register as a sex offender.

Figure-3: List of Individual States and Their Policies on DNA Donations. (National Conference of State Legislature, 2010)

According to Massachusetts law, any person convicted of a felony is required to give their samples to law enforcement agencies within a one year period. And some argue this helps to deter future crimes, as the perpetrator will know his DNA is on file. Felony crimes like murder and rape are viewed in society as heavy crimes, therefore the perpetrator loses more privacy rights than when committing misdemeanors. Although a low level thief does not provide

DNA, some studies have shown that thieves have high propensity of committing other higher crimes against society (Mayer-Schoenberger, 2003).

The following information below is summarized from the states table taken from the National Conference of State Legislatures (2010):

> "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 are murder and sex crime arrests. The Texas law allows post-indictment samples of certain sex offenders. Minnesota's similarly requires a DNA sample after probable cause determination in a charge of one of many serious 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. Starting in 2009, the measure requires arrestee sampling be expanded to arrests for any felony offense. The same measure expanded DNA testing to all convicted felons. Kansas added the requirement that felony or drug sentencing guidelines grid level 1 or 2 crime arrestees provide a DNA sample in its law; and expanded in mid-2008 to all felony arrestees. New Mexico's law also enacted arrestee samples from specified violent felons (National, 2010).

Chapter-5 Conclusions

The author of this chapter believes in the creation of a comprehensive DNA database containing DNA information for the *entire population*. Having more data in CODIS will make it easier to solve crimes and identify people. Selecting only particular individuals to provide DNA samples is not only problematic but an unequal invasion of privacy (Mayer-Schoenberger, 2003). In the same way CODIS can help solve crimes committed by *repeat* offenders, it could help solve crimes committed by *first time* offenders. Implementation of this policy would be relatively easy to enforce, as a cheek swab could be taken for everyone at time of birth. And this approach could help solve the mysteries of unidentified remains, for example the case of a partially mummified body of a man, age 25-40, found off Cape Horn Road in Washington State

on March 21, 2001. Until this day, his body remains unidentified. His DNA profile is available, taken from bones after they found the body, but based on current standards he did not provide his DNA while alive which would have solved his identity (Seattle Post, 2010).

Chapter-5 Bibliography

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PROJECT CONCLUSIONS

The human genome is composed of over three billion nucleotide base pairs, of which 99.9% is identical among all persons. However, the ability of technology to distinguish the 0.1% difference between individuals has given rise to the field of DNA fingerprinting. Soon after DNA fingerprinting techniques were first developed by Alec Jeffreys in the early 1980's, the new technology was used to solve a paternity court case, then it was applied for the first time to help solve a murder case (Colin Pitchfork). With the subsequent invention of PCR in the late 1980's, and its prompt incorporation into DNA fingerprinting, especially for short tandem repeats (STRs), this powerful tool became even more sensitive, needing less of a sample to identify individuals. Since its origins in the field of molecular biology, DNA fingerprinting has been used thousands of times to help solve an increasing number of criminal court cases, identify unknown soldiers, determine the origins of ancient mummies, and track protected wildlife poaching.

There are two main ways in which DNA fingerprints are performed. The first is an RFLP type, which was the first type developed. This type is less prone to contamination, but requires larger DNA samples. The second type is the PCR/STR type, which is far more sensitive, but is prone to contamination unless carefully controlled. The second type has become the most common type performed, with the RFLP type being used as backup when sufficient DNA has been isolated.

Due to early challenges in US courts to poorly collected and controlled DNA evidence, new forensic techniques had to be developed. Initially, challenges to the new technology were few, but as the use of DNA evidence increased so did the challenges against it, especially in

People v Castro 1989, and in *Two Bulls v US 1990.* The successful court challenges were not against the general acceptance of the scientific principle of DNA fingerprinting, but against the human incidental errors in the handling of DNA evidence for individual cases. These successful court challenges to DNA testing technology have been the impetus behind much of the improvements in the standardization of the technology.

A variety of landmark US court cases dicated the way in which complex technological information could be included as evidence in court. Before there was any legal precedent specifically dealing with DNA evidence, it fell under the jurisdiction of the rules governing the admissibility of novel scientific evidence in general. The *Frye Standard* from 1923 was the gold standard used for decades which required novel scientific techniques to be *generally accepted* in the relevant scientific field, deferring to the very experts themselves. A later standard in 1993, *Daubert*, required not only general acceptance in the specified field, but also a sufficient *reliability* of the technique to be included as evidence. With respect to DNA technology, the earliest key precedent *People of New York v Castro, 1989.* In addition to the general acceptance and reliability standards of *Frye* and *Daubert, Castro* added the requirement that laboratory techniques used in the specific case in question be verified by a judge in a pre-trial hearing to be performed correctly with appropriate controls. The Castro 3 prong test was later expanded to 5-prong tests in *Two Bulls v US 1990*, and in *Daubert v Merrell Dow Pharmaceuticals*, 1993. By displaying some of the shortcomings of DNA evidence handling and analysis, these early landmark cases set in motion most of the DNA forensics and fingerprinting infrastructure we use today.

DNA databases are an integral and indispensible part of our national DNA fingerprinting infrastructure. The National DNA Indexing System (NDIS) has an offender index of DNA

profiles of convicted offenders, and another forensic index of forensic samples from crime scenes, both collected from all states. The Combined DNA Indexing System (CODIS) allows the cross referencing of samples at the national level between these two databases, and is often the crux to using DNA to solve criminal cases. Although thousands of crimes have been solved by database hits, the inclusion of DNA profiles in databases comes with ethical concerns. Each state has its own laws determining for which crimes DNA samples must be taken. For example, Massachusetts currently requires people *convicted* of all *felonies* to provide a DNA sample. Other states require individuals *arrested* for some crimes to provide DNA. But due to concerns over civil rights and privacy, whose DNA should be included are debatable. One popular misconception is that medical predisposition data lies within CODIS, and that if someone hacked into this database they could steal private medical information. This is false, as no medical predisposition information is entered into CODIS. However, someone could analyze the *original* DNA sample further than the 13 core CODIS loci to obtain medical information. So the authors of this IQP believe the original DNA sample should be destroyed after obtaining CODIS identification information to prevent anyone obtaining additional medical information. Currently the state of Wisconsin is the only state requiring this. Two authors of this IQP also support the current laws of Massachusetts requiring all *convicted felons* to provide DNA samples to CODIS, but not *arrested* individuals; while one author supports a program in which all individuals must provide their DNA. In any case, the power of DNA databases for solving crimes, recent and old, is indisputable.

In its first two decades, DNA fingerprinting has served society well. Its discriminatory power and reliability have improved significantly, due to a dynamic interplay between the relevant scientific, commercial, legal, and governntal agencies. Continued hard work and

vigilance on the part of all these groups, should further propel DNA fingerprinting technology to aid society in applications for which we have yet to conceive.