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# DNA FINGERPRINTING

An Interactive Qualifying Project Report

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By:

Christopher Deraleau     Christopher Dobens     Jeff Romanosky

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APPROVED:

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

# ABSTRACT

The purpose of this project was to investigate the technology of DNA fingerprinting describing how they are performed, how they are used, and the impact of this technology on society with legal and ethical issues. We conclude this powerful technology has a variety of applications, but it requires strong legislative oversights to help preserve privacy rights.

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# PROJECT OBJECTIVE

The purpose of this IQP was to investigate the technology of DNA fingerprinting and describe its impact on society. Investigated were how DNA fingerprints are performed, what they are used for, and proper procedures for DNA evidence collection and handling. The impact of this technology on society was investigated through a description of landmark court cases that set precedences for allowing DNA evidence in U.S. courts, and via a description of DNA databases, describing what they are used for, and ethical issues surrounding their use.

# CHAPTER 1: DNA FINGERPRINTING DESCRIPTION AND TYPES

## What Are DNA Fingerprints?

DNA fingerprinting and, similarly, DNA profiling are the processes by which minute differences in regions of DNA in individuals are used to create a pattern of bands that are specific to a single person. Unlike traditional fingerprints that present only on a person's fingertips and can be altered through surgery or other means, the same DNA fingerprint can be found in every cell of a person's body, from hair to toe nails. These so-called "fingerprints" aren't visible to the naked eye, or even to a scanning electron microscope, and cannot be altered once left at a crime scene, so they arguably have been called the greatest forensic tool in the history of forensic science. In fact, DNA fingerprints don't exist at all.

In the mid 1980's, Dr. Alec Jeffreys was searching for sites in human DNA that differed from one individual to the next. "Over 99% of the human genome is common to everyone. The tiny variations that do exist are what make people unique" (The Economist, 2004). These differences, known as single-nucleotide polymorphisms (SNPs) are almost impossible to find, so areas of base sequences that are repeated several times in tandem, also known as mini-satellites, are used in their place. The DNA is cut into differently sized fragments at these mini-satellite areas by using a restriction enzyme. Then the fragments are sorted by size using an electric field to pull the fragments through a thick gel. The sorted fragments are then soaked in an alkaline solution to break the DNA into single strands and are then transferred onto a nylon membrane, where a radioactive probe is added. With the help of X-ray film, the sorted fragments become a visible pattern of bands. This pattern of bands is the physical representation of the unique parts of a person's DNA or, as it is commonly called, their DNA fingerprint.

Different techniques for DNA fingerprinting have different visual representations of DNA profiles, but they all try to demonstrate the same idea: that every individual has a specific pattern of DNA that can be associated with them, and only them. However, DNA fingerprinting isn't foolproof; in fact, a DNA fingerprint isn't as exact as most would think. Forensic scientists can only estimate the odds that a random person would share the same specific pattern of DNA differences, not confirm that a DNA fingerprint belongs to a specific individual. In fact, twins and triplets can share the same DNA pattern (monozygotic or identical twins, triplets etc share the same DNA pattern). In fact, when close relatives procreate, the differences in the DNA of their offspring are minimal in comparison to the parents.

**DNA Fingerprinting in Forensics**

DNA Fingerprinting is used extensively in forensic science to aid police in identifying suspected criminals. The first use of DNA fingerprinting in a criminal case was in 1986, by Dr. Jeffreys, who was asked to aid the Leicestershire Constabulary to solve a double-murder and rape case. Dr. Jeffreys's original technique for DNA fingerprinting was not reliable enough to be used as a regular forensic tool, so he developed a more simple method that took advantage of specific mini-satellite regions, and created a "single-locus" probe (SLP) that highlighted areas that are always present in a person's DNA. The only problem with the new method was that the results were no longer individual-specific. In fact, there is a high chance siblings will share the same results.

Thus he chose to analyze multiple SLP results, and the probability that two people will share the same pattern decreased exponentially. Amazingly, the first test of this new technology gave an extremely unexpected result. The evidence did link the two cases together, but the suspect that the police had in custody did not have an even remotely similar DNA fingerprint, which meant that the first test of Jeffreys's SLP system proved a suspect's innocence rather than guilt. The correct suspect, Colin Pitchfork was identified later in another amazing twist of this case in which all local men volunteered to provide DNA samples, none of which matched the DNA on the victim. A woman overhead a man (Pitchfork) brag in a pub that he paid someone to provide blood for him, and this eventually led to the arrest of Pitchfork.

Since its first use in the mid 1980's, DNA fingerprinting has been used extensively worldwide to aid investigators in both linking suspects to crimes and eliminating possible suspects. The FBI is the primary DNA fingerprinting resource for criminal investigations in the United States and actively maintains the world's largest DNA database, the Combined DNA Index System (CODIS), a database which investigators at the local, state, and national levels can use to link crimes based on DNA profiles from evidence left at crimes scenes and from previous convicted felons. "Since the inception of CODIS and the various state-operated DNA databases, hundreds of case-to-case or case-to-suspect 'hits' (i.e. DNA matches) have been reported…DNA databases hold promise for identification of more perpetrators than would be possible without such efforts" (Bieber, 2002).

**DNA Fingerprinting in Paternity Testing**

The first official use of DNA fingerprinting as a paternity investigative tool was in 1985, where it was used to prove that a boy, who was suspected of trying to join his mother in Great Britain on a false passport, was indeed the biological child of the woman in question (The Economist, 2004). The analysis also proved that all of the woman's children shared the same biological father. When used in paternity testing, DNA fingerprinting is not a search for an exact DNA fingerprint match. Instead, DNA is taken from the child and a known biological parent, as well as from the alleged other biological parent. The DNA fingerprint for the child is then compared to the DNA fingerprints of the suspected parents. Since a part of each parent's DNA is passed onto their children, the child's DNA fingerprint pattern should be a composite of their mother's and father's DNA fingerprints. In order to determine parentage, the known biological parent's DNA fingerprint is compared to the child's DNA fingerprint, and the matching fragments are ignored. The remaining fragments are then compared to the alleged parent's DNA fingerprint. If the alleged parent's DNA pattern does not match properly with the remaining fragments in the child's DNA fingerprint, then they are not the child's parent. In this manner, multiple DNA fingerprints can be rapidly compared and analyzed.

In this application, DNA fingerprinting has become an almost infallible resource to determining parentage. In 2001 alone, American labs performed more than 300,000 paternity tests (The Economist, 2004). While comparative DNA fingerprinting has aided in reuniting hundreds of children with lost parents, or helping the courts assign responsibility to the proper parties, it has gained popular support from both the scientific community and the court systems as an accurate tool for use in paternity cases, despite the small possibility of incorrect matches.

**DNA Fingerprinting in Molecular Archeology**

Archeologists and molecular evolutionists use some of the different aspects of DNA fingerprinting to help create theories regarding the spread of genetic traits and familial ties. Using mitochondrial DNA, which is passed on from mother to offspring and has a very small mutation rate, researchers have suggested that the roots of all modern humans came from Africa. By using the average mutation rate of the mitochondrial DNA, scientists have come up with a range of dates for when various areas of the world were settled by modern man.

For instance, scientists believe the DNA sequencing for modern man (Homo sapiens) first appeared in Africa around 200,000 years ago. They then migrated across Africa and traveled into the Middle East and lower Asia some 100,000 years ago. From the Middle East, genetic testing shows that modern man migrated into the main area of Asia some 67,000 years ago and into Europe some 40,000 years ago. From Asia, man traveled to the Americas a seemingly recent 20,000 years after he made it to Europe (Hedges, 2000). Researches have also used DNA from the Y chromosome, or the genetic material passed solely from fathers to sons, to corroborate this theory of modern man originating in Africa, and the subsequent migration to other areas of the world (Gibbons, 1997).

Molecular Archeology is a fast growing use of DNA Fingerprinting. As scientists and anthropologists make new discoveries using this technology our concept of our history and evolution changes. With each passing day, scientists are finding out new things about our ancestors, and are furthering our ability to trace our roots back through history. DNA fingerprinting gives anthropologists a way of validating their theories for human evolution and expansions, as well as helping modern people find a common ancestry. Molecular archeology and DNA fingerprinting have allowed researches to trace modern Europeans back to a 5000 year old body found frozen in the Alps that bears some of the same genetic coding as modern people of that region, proving that their descendants were living in that area for a longer time than anyone believed (Handt et al, 1994).

**DNA**

"Deoxyribose nucleic acid (DNA) is a nucleic acid that contains the genetic instructions specifying the biological development of all cellular forms of life (and many viruses). DNA is often referred to as the molecule of heredity, as it is responsible for the genetic propagation of most inherited traits. During reproduction, DNA is replicated and transmitted to the offspring." (Watson, 2003). DNA is the genetic coding contained in the nucleus of every cell of an organism; it is the material that is passed on to every generation. An individual's DNA is a combination of their parents' DNA, and is made up of a code that tells the cells of the body how to act and what to do. For instance, a person's DNA controls their ability to function as a human, their probability to carry inherited diseases, as well as what eye and hair color they are likely to have.

The nucleus of every cell (except red blood cells) in an organism contains DNA, which is the genetic equivalent of an instruction manual. DNA is transformed inside the cell's nucleus into simple instructions that are to be performed by the cell. For instance, the nucleus of a cell in the iris of your eye takes instruction from its decoded DNA to make your iris have color, be it blue, green, brown or some mixture thereof. The instructions for things such as eye color are inherited from your parents. During reproduction, genetic material from your mother and father combine to create a unique set of instructions for you. While the same base material is combined for siblings, the way in which the two DNA sequences combine can be different, resulting in different results for physical appearances as well. This is why siblings can have the same parents but have vastly different appearances.

Because DNA is passed on through generations of a family, it passes along with it the genes for hereditary diseases such as diabetes and vitiligo, as well as the propensity to experience things as heart disease and cancer. By examining a person's DNA, scientists can give a prediction as to the likeliness that that person may experience a serious illness. It is also possible to tell if a newborn is liable to have an illness such as Down's syndrome or autism. By making use of new technologies it has become possible to give parents advanced warning, and proper counseling on how to deal with children who have such illnesses.

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**Chromosomes**

**"**Chromosomes are very long DNA molecules and associated proteins that carry portions of the hereditary information of an organism" (The National Health Museum, 2005). Because they contain DNA, chromosomes are the actual genetic "builders" that make everyone unique: they are the portions of the DNA that actually determine our various physical characteristics such as gender, eye color, hair color, body shape etc. They are composed of two DNA molecules held together in a nucleosome, or X shape. DNA molecules are held in this shape inside the cell because if unwound, the DNA sequences would take up too much space inside the cell nucleus, so small proteins pack the sequences into these more condensed shapes.

Humans have 23 pairs of chromosomes, with one chromosome of every pair inherited from each parent. For example, a person's gender is specified by the twenty-third pair of chromosomes, which can have several values, the most common being X-Y and X-X; X-Y being the genetic code for a male, and X-X being the genetic code for a female. As a fetus develops, it always receives the X chromosome from its mother. The father's contribution to the chromosome pair dictates the child's gender, in a seemingly random fashion. Each offspring can inherit the same genes from their parents, but it's the individual ways of combining them that dictates the exact results of the combined genes. For instance, say a child inherits a gene for brown eyes from one parent, and green eyes from another parent. If both genes have equal strengths, the child will have hazel eyes, or if one gene is more dominant than the other, the child could have brown or green eyes. The chromosomes are the carriers of this sort of information, and are a vital part of DNA's way of making every individual unique.

**Gene Loci**

Specific locations along the DNA molecule are termed loci. Loci can represent specific genes (whose sequences don't differ much between individuals or they would not function correctly), or can represent "junk DNA" that differs between individuals. These latter loci are analyzed in DNA forensics. At various locations throughout every person's

DNA, a sequence will appear that repeats itself various times in a row; for example GATAGATAGATA. These repeat sequences can be used as kind of highlighter in the DNA that enables scientists to look at patterns in DNA more closely. By using a probe designed to highlight specific loci, genetic researchers can pinpoint exact areas in everyone's DNA to examine. For example, researchers could pinpoint the same sequence in multiple DNA samples and count the number of times the sequence repeats; this is the basis for one type of DNA fingerprinting.

Scientists have identified many different loci throughout the human DNA sequence and use many of them to perform various genetic tests. By taking samples at multiple loci at once, forensic scientists can create an individual's DNA fingerprint. Loci are a valuable tool in the study of DNA: without them, scientists would never have discovered the variation in patterns between individuals, and DNA fingerprinting would not exist.

**RFLP**

"Restriction Fragment Length Polymorphism (RFLP) is a technique in which organisms may be differentiated by analysis of patterns derived from cleavage of their DNA. If two organisms differ in the distance between sites of cleavage of a particular restriction endonuclease, the length of the fragments produced will differ when the DNA is digested with ~~a~~ restriction enzyme. The similarity of the patterns generated can be used to differentiate species (and even strains) from one another" (Hill, 2004) or to distinguish one human from another. Simply put, DNA is cut into pieces using a restriction enyme that recognizes a particular string of bases (say GAATTC for the enzyme EcoRI). The location of the GAATTC sequences in the DNA sample can differ from person to person, or species to species, so the length of the fragment that the enzyme cuts out differs.

When the length of this fragment is compared to a known sample, there is a clear distinction between same-length fragments and different-length fragments (see Figure 1). By combining the results from many RFLP sites, scientists can create a very distinct pattern of variation, and can use this pattern to compare known samples to unknown samples and determine if they came from the same source. In this way, RFLPs are used in DNA fingerprinting and forensic science, and for analyzing DNA in all areas of research.

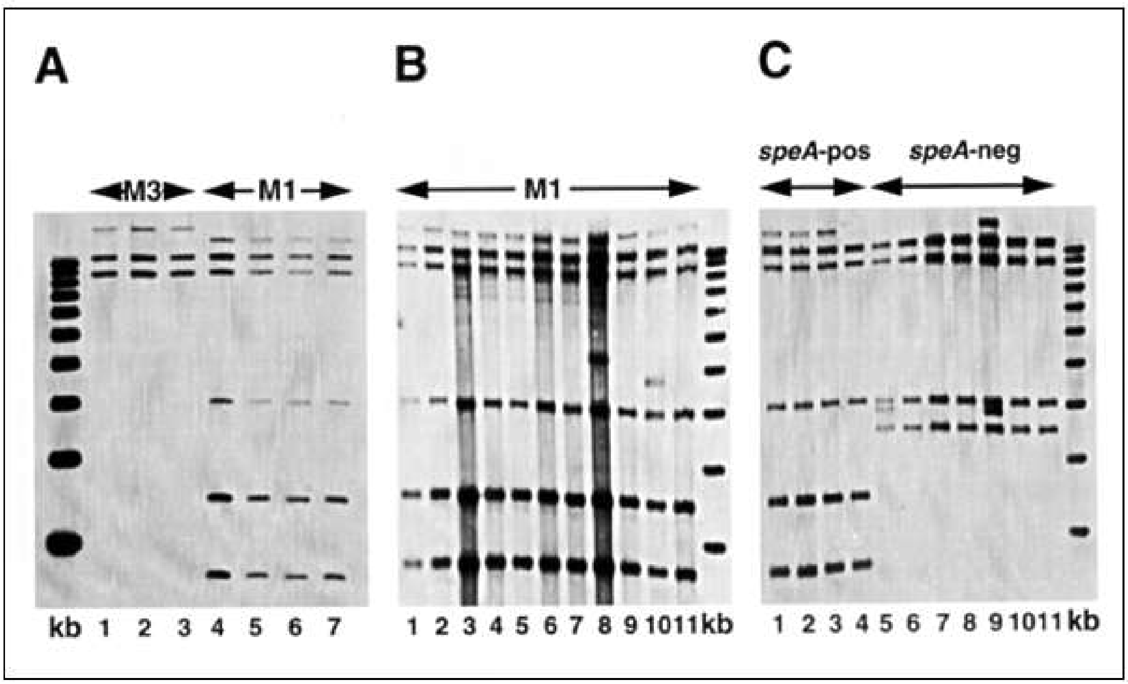


Figure 1: Sample RFLP Fingerprint (Hoe et al, 1999).

**VNTR**

On some chromosomes, there are regions in the DNA where a short sequence repeats itself back to back, as many as 30 times at one location. “Since these repeat regions are usually bounded by specific restriction enzyme sites, it is possible to cut out the segment of the chromosome containing this variable number of tandem repeats of VNTR's, run the total DNA on a gel, and identify the VNTR's by hybridization with a probe specific for the DNA sequence of the repeat" (Huskey, 2004). Thus this analysis is similar to the RFLP but it analyzes specific DNA locations known to differ by simple base repeat patterns (Figure 2). These groups of repeating sequence are the result of the combining of DNA during reproduction. When the DNA from two parents are combined, it is possible that they have a similar sort of repeating DNA sequence at a specific location, and at this location, the two sets of repeat sequences add to create one larger repeated grouping. For instance, if one parent has a six group repeat sequence of GTCA, and the other parent has an eight group repeat of the same sequence at the same location, then the offspring can have a similar repeat sequence with as many as fourteen groupings. By analyzing these sorts of groupings, it is possible to create a distinct distribution of repeating groups. Even in the same direct line of offspring, it is possible that no two offspring will have the exact same number of repeats for each specific grouping. This means that analyzing multiple groupings can lead to a personalized pattern for every individual, and thus is another method of creating a DNA fingerprint.

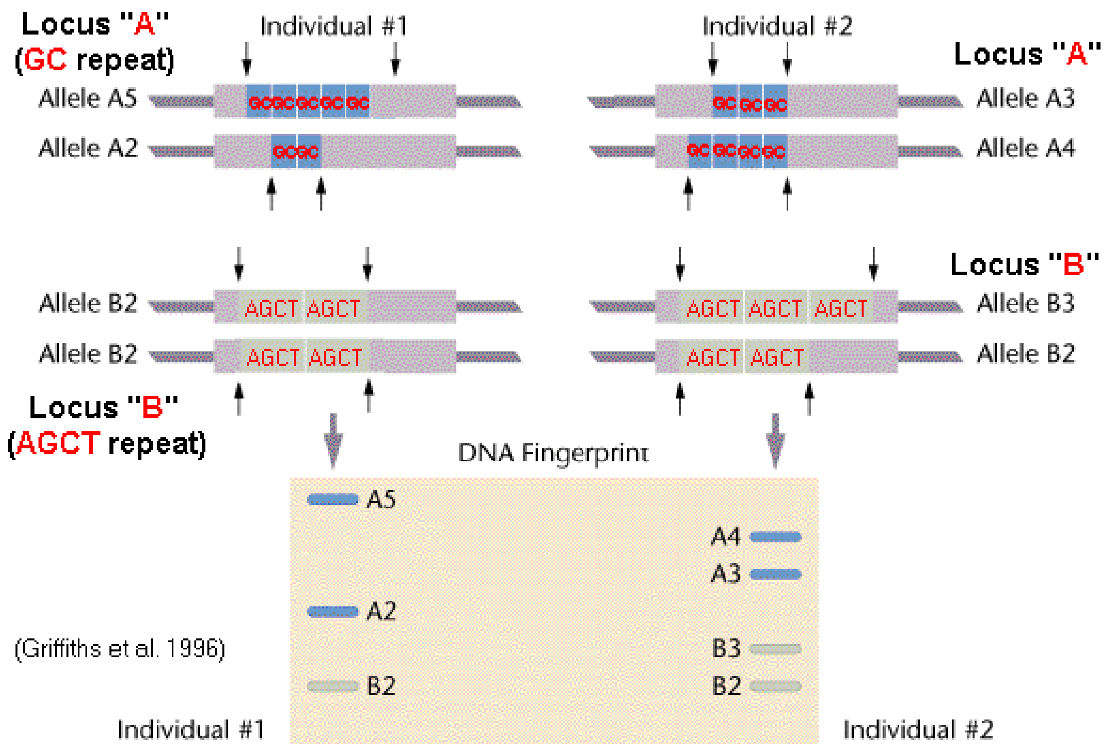


Figure 2: Sample VNTR Fingerprint (Carr, 2003).

## STR

"Short tandem repeats, or simply STRs are short sequences of DNA, normally of length 2-5 base pairs, that are repeated numerous times in a head-tail manner" (The Biology Project, 1996). Similar to VNTRs, STRs are groups of repeating code throughout our inherited regions of DNA that can be useful in identifying variation among individuals. Because STRs are shorter in length than VNTRs, the STRs can easily be amplified by polymerase chain reaction (PCR) (see below), so you do not necessarily need hybridization to a probe to visualize them. Because of their ability to be amplified by PCR, the analysis can be performed on very small forensic samples. Because of this, and their ease of visualization without probe hybridization, STR analysis has become the favorite technology for forensic analyses (Figure 3).

STRs are associated with specific loci throughout the DNA sequences of individuals and are one of the core devices for the CODIS DNA database. STRs are present throughout our non-coding DNA and have become the primary points of interest in DNA fingerprinting and profiling due to their common occurrences at several specific loci in the DNA sequences. By taking advantage of several specific STR loci, DNA profilers have created large databases of individual DNA variations to aid in the capture and identification of criminals. STRs are a viable tool for DNA Forensics and the future of DNA science.

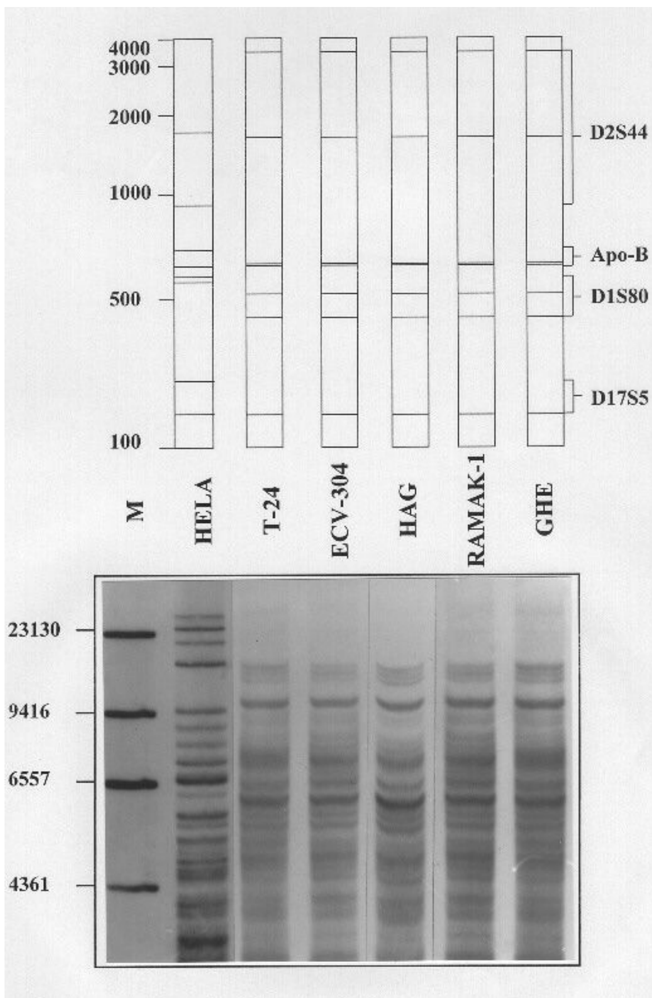

Figure 3: Sample STR Fingerprint (German National..2004).

**PCR**

"Polymerase Chain Reaction, or PCR for short, is a technique for amplifying a specific region of DNA" (Hill, 2004). Basically, a sample of target DNA (say from a crime scene) is cut from the full DNA sequence using two restriction enzymes. The portion of DNA is then unzipped using high heat to form two halves of the DNA sequence. It is then put into a solution of free DNA bases, and primers to initiate the polymerization process where each half of the unzipped DNA pairs its bases with the necessary opposite bases, to form two complete strands of DNA. When this sequence is performed on several samples, the amplification of the target DNA can be in the millions, resulting in a large quantity of DNA in which to analyze from a small seed sample of DNA (Figure 4). PCR is the most useful tool in DNA forensics because it allows a small portion of sample DNA, that by itself might not be enough to generate a DNA fingerprint, to be amplified to levels that allow for multiple fingerprints to be made, as well as enough for a thorough analysis.

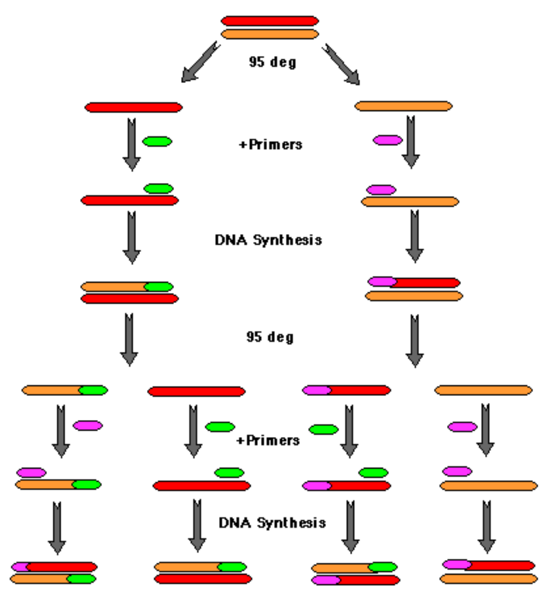


Figure 4: Example Polymerase Chain Reaction (Orme, 2001).

# CHAPTER 2: DNA FORENSICS

In the past, DNA evidence was collected haphazardly, and at times was not admitted into court because poor techniques resulted in improper treatment of the evidence. This can lead to contamination of many samples and invalid results. Developing proper handling and collection guidelines has helped prevent contamination of DNA evidence and has increased its rate of admission into the courtroom. Teaching investigators and law enforcement officers to adhere to these guidelines has resulted in DNA evidence quickly becoming an invaluable tool in the prosecution of criminals. Outlined below are important guidelines that crime scene investigators should follow.

**Preventing Poor Collection of DNA Evidence**

The manner of collection of DNA evidence at a crime scene is the most important determining factor of the equation of DNA profiling and its admittance as evidence. If DNA evidence is collected improperly at the crime scene, a defense attorney can argue against its acceptance into court as a valid article of evidence. A crime scene investigator who correctly documents and identifies evidence collected at a crime scene is a great asset to the local district attorney and to those looking to use DNA evidence to aid in convictions.

Proper training is the first step toward preventing improper collection of evidence. By teaching those who will be gathering evidence at a crime scene the proper procedure for collecting evidence, mistakes in the collection can be prevented. The most important thing is to train all personnel, and not just the crime scene investigators. By teaching the responding officers and other emergency personnel to properly address and secure a crime scene, contamination of both the scene and the evidence can be eliminated. Properly preventing the personnel at the scene from disturbing the area can aid investigators in getting a clear picture, and accurate documentation of the site.

Conversely, by not training personnel how to properly secure and maintain a crime scene until investigators arrive risks contamination of the evidence. If the first responding officer to a scene just nonchalantly wanders around picking things up and moving them, the scene and the evidence becomes contaminated, putting the entire investigation at risk of failure. By training personnel to take the proper precautions to not disturb the evidence, one major source of contamination is eliminated. By teaching them to secure the crime scene from both onlookers and other officers or personnel, the evidence at that scene can be preserved in the exact state at the climax of the crime. For instance, at the scene of a homicide, the first responding officer can prevent the disruption of any evidence surrounding the body such as possible murder weapons or trace evidence left behind by the killer by cordoning off the area surrounding the body. If the area isn't secured, it is possible that other people in the area can either disturb the necessary evidence to help solve the crime, or they can accidentally contaminate the evidence.

"An investigator should take a slow and methodical approach to collecting and preserving evidence. The only time that an investigator should make rapid decisions concerning evidence is when the evidence is in danger of being destroyed or compromised" (Schiro, 2001). Training every individual who might encounter a crime scene to adhere to strict guidelines concerning evidence collection can ensure that crime scene investigators will be able to properly collect and preserve the evidence. Teaching the actual scene investigators to be thorough and methodical in their collection of evidence can ensure that all evidence will be properly gathered and documented, and that the evidence will not be compromised or contaminated.

**Preventing Contamination of DNA Evidence**

There are several methods used to collect and catalog evidence at a crime scene; when it concerns potential sources of DNA evidence, special care must be taken to prevent the evidence from being cross contaminated by itself, or with outside sources. The largest source of DNA evidence at a crime scene is likely to be the blood or other bodily fluids from both the perpetrator and the victim (Figure 5). How to collect this sort of evidence is based largely on the state of the evidence. Stains from body fluids on walls, floors and objects in the immediate area can be very simple or very difficult to collect.

Figure 5: Potential dried blood stain on shirt (Nature, 2004).

Stains on items of clothing are the easiest to collect. It is best to take the entire item, ensure that the stains are completely dry, and place the item in a paper evidence bag (Figure 6). If necessary, pieces of paper should be used to separate individual stains from each other so as to prevent contamination. Paper should be used in lieu of plastic bags so that the item and stains can have proper ventilation around them: if stains are still damp, items placed in plastic bags can be affected by bacteria that can damage or compromise the potential DNA evidence. Each item should be placed in individual bags, with proper labels dictating who collected the evidence, where it was collected from, a short description of the item, as well as any identifiers for case, date, time etc. Any item that is considered for evidence that can be collected in its entirety should be collected in this manner. This ensures that the entire item is available for sampling, and eliminates the need for a separate control sample.

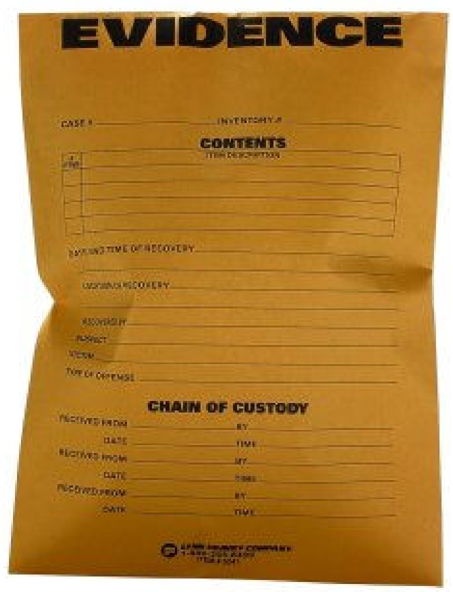


Figure 6: Sample Evidence Envelope (Lynn, 2005).

Dried stains on items that can not be taken in their entirety, such as carpets or mattresses, should have the areas surrounding the stain cut from the item, as well as a sample control area with no stain removed from close to the stain. The control sample is necessary to eliminate any latent DNA from things like the individual fibers in the item, as well as to provide a background sample for the investigator to compare against the sample stain. Proper care should be taken to ensure that any stained item is allowed to dry completely before being placed in a paper evidence bag. If it is not possible to allow the evidence to dry completely at the scene, proper care should be taken to ensure that any wet or damp stains not remain in evidence bags for more than two hours to prevent possible bacterial growth on the sample. Wet items should be brought to the testing lab and placed in a manner that will allow them to dry prior to being analyzed or placed back in a proper evidence container.

Stains on items such as concrete floors or walls, or any other object that would be impossible to remove from the crime scene (Figure 7) should have samples taken with a sampling medium such as a cotton swab or cotton fibers. There are special techniques used for taking samples of stains from immovable objects. Care should be taken to ensure that the sampling medium does not become contaminated prior to use, as incorrect preparation can lead to inaccurate results. Cotton sampling mediums should be moistened with distilled water to allow correct transfer of the stain to the cotton. The easiest tool for this is the cotton tipped swab, which requires no handling of the sampling medium at all. The swabs can be dipped in distilled water by their handles, and then used to absorb the stain, all without touching anything other than the wooden handle. This results in a virtual contamination-free way of sampling stains.

Figure 7: Example of blood stain on immovable object (Al-Jazeerah..2004).

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Outside of good technique for collecting stains, other considerations should be made by crime scene investigators in way of safety gear and dressing to prevent contamination. Latex or rubber gloves are a must in order to prevent accidental contamination by touching or moving evidence with bare hands. Care should be taken to dress appropriately, with all necessary safety gear, including gloves, safety glasses, comfortable hard-soled shoes, as well as close-fitting clothes so as to prevent accidental touching or snagging on evidence. Investigators should try to have a spare change of clothes available if it becomes necessary to visit another crime scene so as to not accidentally contaminate evidence at one scene with evidence from another recently-worked scene.

By combining good sampling technique with appropriate attire and good training, contamination of evidence containing DNA can be prevented. It is imperative that all personnel at the scene adhere to the same guidelines in an attempt to maintain the integrity of the evidence and the case. Poor or sloppy work by field investigators or unprofessional conduct can compromise the scene and can lead to violent criminals not being brought to justice.

**Likely Evidence to Contain Forensic DNA**

When examining a crime scene, investigators should take into special consideration any substance that might contain DNA and keep in mind that extra care needs to be taken when collecting such evidence. While most investigators will immediately think of blood and seminal fluids as containing DNA, there are other possible sources of DNA at crime scenes, some of them normally just thought of as physical evidence, and never considered for DNA testing.

For example, one might associate cigarette butts or lipstick smears on glasses as just being coincidental, but the traces of saliva contained in both can carry DNA. While it is difficult to extract and isolate this DNA, it can be a valuable source, and well worth the time in the attempt. Other evidence likely to contain DNA also includes things such as ski masks, envelopes and stamps, or any other object that a perpetrator might have licked, breathed through, or touched with their mouths. An often overlooked possible source for things such as forced entries or break-ins, is the non-functional end of any tools such as flashlights, as one might have been placed in the suspects mouth to free up their hands.

Seminal fluids are excellent source of DNA evidence, and can often be found at the scenes of rapes, or among dirty clothing, bathrooms or bedrooms. The sheets of a bed at any crime scene should be looked over thoroughly for any trace stains of sexual activity.

Clothing at the scene should also be examined for any stains, or in the case of a rape, the suspect's undergarments should be analyzed for potential stains, and in any case, should be taken into consideration for evidence and as a likely source of DNA evidence. When it comes to rape cases, a vaginal swab of the victim can lead to possible seminal fluids from the attacker and is the most likely source of DNA evidence left in a rape case. In fact, many rape cases have been solved because the attacker left behind traces of semen on the victim's clothes, or in some cases, vaginal fluids were evident on the attacker's clothing.

Blood stains are the most abundant source of DNA evidence at most crime scenes, mainly because the average human body contains approximately six quarts of blood. This means at a stabbing, shooting or any other type of violent crime scene, there is potentially six quarts worth of DNA-containing evidence. While it is very unlikely that the entire amount of blood contained in a human body will be accountable as stains or pools at a crime scene, most violent crimes will result in at least a portion of it being displaced about the scene in the form of blood splatter marks or pools near the body. While this DNA might not seem helpful in finding the perpetrator, it is helpful in the case of identifying the victims. During some violent crimes such as shootings or stabbings, there is a potential for the suspect to struggle with the victim and be injured. When this occurs, the possible transfer of blood from injuries the suspect receives to the skin, clothing or other items associated with the victim can help lead investigators to a suspect. This resultant blood transfer is a valuable source of DNA at a crime scene, and has helped lead investigators to several suspects over the years.

The average human loses fifty to one hundred hairs every day (Pistone, 2005); more can be shed on a daily basis if the person wears a hat or brushes their hair. This regular hair loss can lead to another source of DNA containing evidence (Figure 8). At the root of every hair on the human body is the group of skin cells that creates the skin, also known as the follicle. If hair found at a crime scene has this cell attached, it can be used as a source of DNA to aid in identifying a suspect. Hair without this cell is not useful for identifying more than a hair color or if a suspect dyes their hair: the follicle or root is the only DNA-containing part of hair. Likewise, actual skin cells are a good source of DNA as well. During a struggle there is a potential for the victim or attacker to be scratched by the other individual, which can lead to skin cells being lodged under the fingernails. By analyzing the DNA in these cells, law enforcement can make a link between victim to attacker or vice versa.

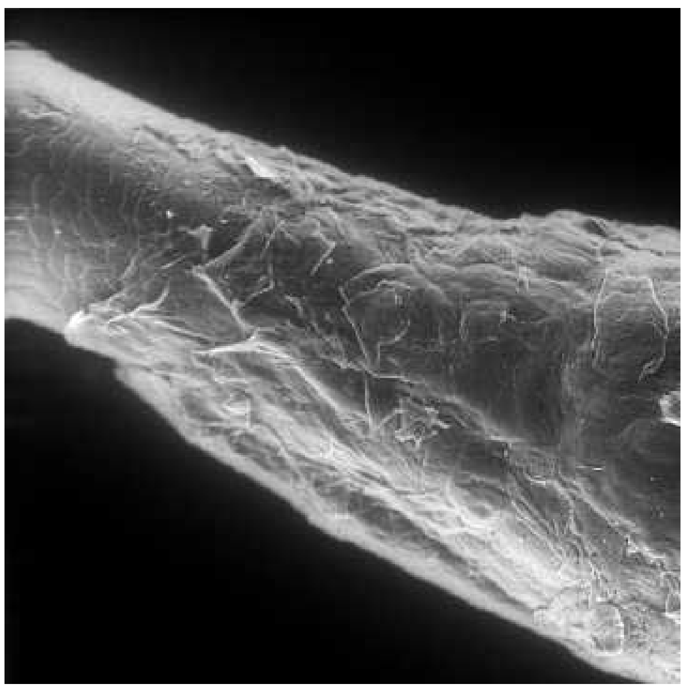

Figure 8: Magnified view of a human hair including root (Minnesota…2005).

Some biological samples will not contain DNA that can be processed for identification or even at all. For instance, human waste products like urine or fecal matter do not contain any any useful DNA (it is highly degraded), though in some rather extreme instances involving cannibalism, fecal matter can potentially contain undigested skin or other cells from a human body that can be analyzed in an attempt to link suspect to victim, though the digestive acids can alter this DNA to make it impossible to get accurate results, and it's quite difficult to separate the undigested bits from the digested bits.

**Collecting DNA Evidence at Aged Crime Scenes**

Aged crime scenes are an extremely difficult challenge for investigators because a great deal of the DNA-containing tissues have likely deteriorated into a state that does not allow for DNA to be extracted. Also, any surrounding evidence is likely to have been altered by the environment, animals, or other sorts of disturbances. "Common sense and knowledge of previously approved practices seem to be the rule when deceased individuals are concerned, particularly when severe decomposition is present and blood work not practical. If hairs are to be submitted, make sure the collector obtains pulled hairs. The tissue associated with the hair root is needed in the DNA analysis. Other samples which may be suitable for DNA analysis include: bones (rib or long bones preferred), teeth, muscle tissue, and associated items which may be found with the body (hairbrush, toothbrush etc.)" (Kramer, 2002).

The associated property is likely to be the only source of suspect DNA at an aged crime scene since it is removed from the decaying body, so it is of importance to collect any and all items surrounding the area, even if it does not appear that they have anything to do with the crime. It is possible that items that weren't present at the time of the crime picked up trace evidence from the suspect that may be helpful in identifying a suspect. At most aged crime scenes, the physical evidence of the crime will have long disappeared, and the majority of the investigation will simply lead to identifying the victim and not be overly helpful in aiding investigators in finding a suspect.

Old crimes are not the easiest to investigate due to the effect of the environment on evidence, in particular on DNA evidence. Over time, exposed tissue decomposes, blood stains get washed away by rain or disturbed by blowing winds, items that were at the crime scene can be disturbed by animals, or even carried away by others who don't realize that a crime was committed in the area. Murder weapons can be found far from the scene if they are discarded nearby, and then picked up by vagrants or opportunistic criminals, or even accidentally by children.

The most important parts of aged crime scene investigations are preserving what evidence is collected, and getting accurate results of DNA analysis, just as in the contemporary investigations: the evidence and DNA profile are the most likely comparative sources if a suspect is found. PCR is likely to be performed since the quality and abundance of DNA will be low. The DNA evidence is especially important because it is the most likely item to tie the suspect to the crime scene, and without accurate DNA analysis and properly preserved DNA evidence, there is a great chance the killer could walk free.

**Storing DNA Evidence to Prevent Degradation**

Several environmental conditions lead to the degradation of DNA in evidence, the leading condition being extremes of temperature. In order to keep DNA samples from degrading over time, it is best to store them at or below room temperature. In most cases, maintaining the sample at a temperature slightly above freezing, so as to keep prevent any ice formation from occurring, is optimal. Liquid samples of blood or semen should be stored below freezing, so that the integrity of the sample is maintained, or they can be turned into controlled stains and stored with other evidence at room temperature. Proper temperature is key to maintaining the sample in the same state as it was taken.

Moisture is also a factor that can lead to the degradation of DNA evidence in storage. If a sample is stored in humid or wet conditions, the same could be attacked by bacteria and be damaged beyond use. If investigators aren't careful to ensure that their samples are stored dry, the moisture in the sample can be the most harmful factor in the degradation of the DNA. Bacterial growths can destroy the evidence and the DNA contained in it. If a sample with bacterial growth is analyzed, the DNA profile will contain a portion of the bacteria's DNA, which will lead to inaccurate results concerning the suspect DNA profile.

Incorrectly stored samples will lead to degradation of the DNA they contain, so extreme care should be taken when preparing samples for storage, and extra consideration should be taken in the cases of items that might sit in storage for long periods of time. Proper preparation can help DNA evidence last for a good part of a century, but regardless of how well prepared a sample is, time is DNA's biggest enemy. Even properly stored DNA eventually degrades over time, so accurate results at the time of initial processing should be kept and stored with just as much care as the samples themselves, so in the future, even if the samples degrade, the original analysis will still be available for use as evidence. Preventing the most damaging conditions can help DNA evidence last longer and will make it easier to admit into court.

# CHAPTER 3: LANDMARK DNA CASES

The acceptance of DNA evidence in U.S. courts has not been a straightforward process. This chapter examines several landmark cases that helped establish precedence for allowing technical evidence into courts.

**Frye v. United States, 1923**

James Alfonzo Frye was brought to trial and convicted of second degree murder in 1923. Frye was subjected to, a then new and not necessarily accepted lie detector test. Frye passed the test that took hints from blood pressure changes to determine lies told by the subject. After passing the test, the defendant's counsel wanted the test results and the testimony of the scientist who conducted the test to be presented in court. The government objected to this as they did not see it as solid scientific backup; the objection was sustained. Counsel then offered to have the test done in court; but this offer was also rejected by the court.

The theory of lie detection is based on the observation that often when one lies, blood pressure increases. In theory, lying takes an effort while truth is spontaneous, therefore no changes in a suspect's blood pressure would "prove" he is telling the truth. The problem is one can sometimes voluntarily control blood pressure to fool the test. So to date lie detector evidence is not acceptable in courts.

With counsel from his attorneys Foster Wood and Richard V. Mattingly, Frye's conviction was appealed in the Court of Appeals of District of Columbia. The appellate court, however, agreed with the judgment of the lower court stating that the technique of lie detection was not generally accepted in the scientific community, and Frye's guilty verdict stood still. This event meant a lot to modern law as it set a legal precedence where a standard of scientific evidence admission, now known as the 'Frye Rule' comes into effect. This rule, although highly criticized for being overly stringent, would be followed for decades.

A common question that arises when thinking about lie detectors is the difference between the rises in blood pressure due to general nervousness about the test as apposed to the rise in blood pressure due to a lie. This difference is easily detected because the pressure rises associated with lying are more pronounced and clear than in a state of general nervousness. If the subject was telling the truth and was just anxious, the blood pressure levels would start off high and gradually decrease as the subject continued the test. Because the results can be controlled by some individuals, it is not a reliable test, and remains inadmissible to this date.

The Frye case also established precedence for allowing expert testimony when the technology is too complicated to be understood by the average juror. As stated in their brief:

> "The rule is that the opinions of experts or skilled witnesses are admissible in 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 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 a particular science, art, or trade to which the question relates are admissible." *(Frye v. U.S., 1923)*

Many cases at the time yielded to this general rule, but eventually a problem arose trying to determine the point at which a technique has gained general acceptance, and eventually the Federal Rules of Evidence were established to aid the process.

This case laid forth a new standard for admitting expert testimony. The "Frye Rule", as stated by the appellate court states "While courts will go a long way in accepting expert testimony, deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs." (*Frye v. U.S., 1923)*

**Downing v. United States, 1985**

On January 25, 1985, John W. Downing was convicted in the United States District Court for the Eastern District of Pennsylvania, on charges of mail fraud, wire fraud, and interstate transportation of stolen property. Downing, as a member of the Universal League of Clergy, planned to defraud vendors. The ULC began operation in Bedford, MA and then Blue Bell, PA.

In this scam, which the defendant was accused of being involved with, the ULC would contact vendors, falsify information to establish credit with the vendors, sell the acquired goods and then split without ever paying the vendors back. The ULC would go to trade shows, meet some vendors and express some interest in their products. After that, they would provide the vendors with fake credit and bank references. The addresses used were mail drops where the requests for reports would be sent and then favorable reports were sent back to appease the vendors. When the vendors would give their products to the ULC, they were more than likely to never see them again. The Universal League of Clergy would split out of town, and sell the products for quite a nice profit.

When brought to trial, Downing was charged on the basis of twelve eyewitness identifications of the defendant, whom they all knew as Downing's alias, Reverend Claymore. The eyewitness accounts varied in duration. The vendors spent anywhere from five minutes to forty-five minutes with Reverend Claymore. The defense tried to use expert testimony to expose the unreliability of eyewitness accounts in general. The district court, however, did not allow the expert testimony for the defendant despite the facts that the accounts occurred in too short a period of time, were "innocuous in circumstance" and the timeframes between meetings and identifications were considerable. The district court based its denial of admittance of the expert testimony on the grounds of two arguments: (1) "the witness would 'usurp' the function of the jury; and (2) there was additional evidence such as fingerprints and handwriting." (U.S. v. Downing, 1985)

The defendant's counsel appealed this decision in the United States Court of Appeals, Third Circuit. The appeals courts found the district court in fault on the grounds of denying admittance to the expert testimony. The appeals court ruled that the district court's second argument in which they claim additional evidence such as fingerprints and handwriting does not hold water because there is no such available evidence. As for the district court's first argument, the appellate court reasoned that "several courts of appeals have also excluded eyewitness testimony because they felt that the jury can use common-sense to sufficiently weigh the arguments in a proper cross examination. Conversely, the Third Circuit Appeals Court found that under certain circumstances, this type of testimony can satisfy the 'helpfulness rule' or Rule 702. (U.S. v. Downing, 1985) The court cited an example from *State v. Chapple, 1983* in Arizona, where a similar situation occurred. In this case, the Supreme Court of Arizona set aside a guilty verdict in consideration of a new trial where the expert testimony that was excluded from the prior trial would be included in the new one. The expert was prepared to testify the following:

> (1) the "forgetting curve," i.e., the fact that memory does not diminish at a uniform rate; (2) the fact that, contrary to common understanding, stress

> causes inaccuracy of perception and distorts one's subsequent recall; (3) the assimilation factor," which indicates that witnesses frequently incorporate into their identifications inaccurate information gathered after the event and confused with the event; (4) the "feedback factor," which indicates that where identification witnesses discuss the case with each other they can unconsciously reinforce their individual identifications; and (5) the fact that the studies demonstrate the relationship between the confidence a witness has in his or her identification and the actual accuracy of that identification. (U.S. v. Downing, 1985)

The Arizona Supreme Court concluded that each of the said variables was beyond the common knowledge of a juror, and that the expert witness testimony in the original case would have "assisted the jury in reaching a correct decision." (U.S. v. Downing, 1985)

The Downing v. United States case also established the idea of a pre-trial hearing to view potential evidence to decide its subsequent admissibility in the trial. The appeals court stated, under Rule 702, that a district court should rule on the admission of novel scientific evidence through a initial hearing that should focus on "(1) the soundness and reliability of the process or technique used in generating the evidence, (2) the possibility that admitting the evidence would overwhelm, confuse, or mislead the jury, and (3) the proffered connection between the scientific research or test result to be presented, and particular disputed factual issues in the case." *(U.S. v. Downing, 1985)*

In joining with numerous other courts, the Third District court focused more on the reliability of the scientific evidence than on the Fry Rule of general acceptance talked about earlier. They cited three cases in support of their decision. The first case was *State v. Temple*, where "evidence based on new scientific methods will be admitted when the demonstrated accuracy and reliability of the method have become established and recognized." (*State v. Temple, 1981*) The second case was *State v. Kersting*, where "evidence based on a scientific technique that is not generally accepted may be admitted if there is 'credible evidence on which the trial judge may make the initial determination that the technique is reasonably reliable'." (*State v. Kersting, 1981*) The third case was *D'Arc v. D'Arc* where "recognizing a distinction between the general acceptance standard and a standard based upon reliability, [the judge may admit] evidence that satisfies either test." (*D'Arc v. D'Arc, 1978*)

The District Court accepted that "the control of the order of proof at trial is a matter committed to the discretion of the trial judge" (*U.S. v. Continental Group, 1983*), however they did not "prescribe any mandatory procedures" the district courts are required to follow when scientific evidence is involved. The court did however feel that the determination of such scientific evidence's reliability should be conducted in a "in limine [pre-trial] hearing" where court time would not be used and the jury would not witness it. (*U.S. v. Downing, 1985*) This hearing is intended to the relevancy of the evidence under Rule 403 which states: "although relevant, evidence may be excluded if its probative value is substantially outweighed…by considerations of undue delay, waste of time, or needless presentation of cumulative evidence," as well as the risk of admittance under Rule 702.

**Andrews v. State, 1987**

February 21, 1987 was the morning that Tommie Lee Andrews was accused of breaking and entry to a residence and raping the woman who lived inside. The victim was held down with her mouth closed while her life was threatened with a straight edge razor blade if she were to see the attacker's face. The woman was cut on her face and several parts of her body. The assailant forced vaginal penetration on the victim, stole her purse containing a small amount of money, and then ran off.

In an examination of the victim after the attack, semen was found in the victim's vagina. As testified by an expert witness, both the victim and aggressor were of blood type O, however, the victim was not a secretor where as the aggressor was. A secretor is a person who has a trace of their blood type inside of their body fluids such as saliva and semen, sometimes allowing blood type determinations on non-blood samples. The swabs that were analyzed contained blood type O, which the state presented as evidence connecting Andrews to the crime scene, even though it was possible that the blood could have been transmitted to the swab through by the victim in the examination.

Going beyond mere blood type, this case presents the issue of the admissibility question of the DNA fingerprint evidence collected. The test results from Lifecodes Corp., which the trial court admitted as evidence, convicted Andrews of the said crime. In *Downing v. U.S.*, the Third Circuit Court decided that when the scientific evidence in question has no established track record or general acceptance, the court may look to other factors to determine the reliability it. Since DNA fingerprinting was one of these new types of evidence, the court included the consideration of the "novelty of the new technique, the existence of a specialized literature dealing with the technique, the qualifications and professional stature of expert witnesses, and the non-judicial uses to which the scientific techniques are put." (*Andrews v. State, 1987*)

This case provided a strong overall analysis of DNA fingerprinting technology at that time. The expert testimony of Dr. David E. Housman brought to light the current scientific opinion of DNA fingerprinting. He explained how different additives could be added to cut DNA strands at different designated points. In this process, known as 'restriction fragment length polymorphism', it would be possible to compare different

DNA strands by using a reagent that recognizes small differences found within. This use of chemical reagents won Dr. Arber the Nobel Prize ten years prior. Further, Dr. Housman testified that DNA fingerprinting is widely accepted and used in the scientific community. It is often used for study, diagnosis and treatment of genetic diseases. (*Andrews v. State, 1987*)

The DNA evidence was admitted because it was seen as relevant and helpful to the jury to make a correct and sound decision. However, there was still a question as to whether the value of such evidence was more or less important than the "potential prejudicial effect." (*Andrews v. State, 1987*) At the time of trial, DNA fingerprinting had been practiced for 10 years, so it was accepted by the court to be a "reliable, well established procedure, performed in a number of laboratories around the world," and also used in the "diagnosis, treatment, and study of genetically inherited diseases." (*Andrews v. State, 1987*) This non-judicial use and acceptance of the practice presents to the court that the evidence is indeed reliable as in conjunction with Downing's ruling that outside factors may be used when looking at evidence of a new and not necessarily universally accepted form.

In concurrence with a second Part of the Downing ruling, the court also considered the availability of specialized literature dealing with the method. At the time, DNA fingerprinting was not a hard topic to find a book about. The manager of forensic testing at Lifecodes, Dr. Michael Baird, testified that the company kept record of all scientific journal articles and publications that dealt with DNA testing.

Further testimony stated that if any problems occurred with the process, the results would not just be false but would also be erroneous. To prevent this, more DNA control samples were used to find errors and exclude them, thus increasing overall confidence in the data. Eventually, the DNA evidence was allowed, and the guilty verdict remained.

**Castro v New York, 1987**

After being accused of the murder of a seven-month pregnant woman, on February 5, 1987, Joseph Castro was arrested. Vilma Ponce, the victim, was stabbed to death also resulting in the death of her unborn child. At the time of being arrested, blood was found on the wristwatch Castro was wearing which was suspected as being the blood of the victim. The prosecution sought to build its case on proof that the blood on the watch actually came from the victim. Blood tests were done, and through DNA fingerprinting techniques, the blood was found to be a match to the victim Ponce as suspected. In response to these results, the defense argued that the tests were done incorrectly and that the results were not dependable, so the Castro case evolved into the most scathing review of DNA fingerprint technology performed at that time. The Bronx County Supreme Court established that: "(1) with generally accepted scientific tests performed properly, DNA identification evidence is admissible, and (2) the testing laboratory did substantially perform scientifically accepted tests with regard to evidence of exclusion, but failed to use generally accepted scientific techniques for obtaining reliable results with respect to evidence of inclusion." (*People v. Castro, 1987*)

This case set precedence for future cases with the development of the 'Three Prong Test.' The court developed this test to assist future court decisions that involved DNA evidence. The test stated the following:

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

On the question of the first prong, the court stated that "the evidence in this case clearly establishes unanimity amongst all the scientists and lawyers as well, that DNA identification is capable of producing reliable results" (*People v. Castro, 1987*). They backed this stance with the introduction of a publication called *DNA Typing: Acceptance and Weight of the New Generic Identification Tests* by Thompson and Ford. This publication notes that there is nothing controversial about DNA typing in the scientific community, and that the repeated successful results from the test show that there should be no questions asked when admissibility is an issue. Therefore, the first prong of the three prong test is met.

When the second prong is applied, the court finds that "the techniques and experiments performed in this case are not novel or recently discovered. They have been in use in laboratories in the conducting of DNA analysis in diagnosis, clinical and experimental settings for years" (*People v. Castro, 1987*). In 1987, there were eight experiments and procedures used in these cases. The first six experiments or procedures, known as "Southern Blotting," as well as the seventh and eighth procedures which deal with interpretation and population genetics, have all gained scientific acceptance. This demonstrates that the second prong of the three prong test passes, and that there are techniques that are commonly accepted that can produce reliable DNA identification results.

To address the third prong of the test, the court decided that "a pre-trial hearing should be conducted to determine if the testing laboratory substantially performed the scientifically accepted tests and techniques, yielding sufficiently reliable results to be admissible as a question of fact for the jury." (*People v. Castro, 1987*) When addressed, the laboratory was found to be capable of conducting such tests as they usually follow the accepted scientific procedure correctly, within a reasonable degree of scientific certainty, but failed to do so in this specific case.

In consideration of the 'Three Prong Test,' the court ruled that only some of the available DNA evidence in the case was admissible as evidence. The results that excluded suspects from the crime were deemed admissible, whereas the results that included suspects in the crime were not. The testing laboratory, in this case of inclusion testing, failed in several major respects to use generally accepted techniques properly. Thus the DNA evidence was not allowed in the Castro trial.

One outcome of the Castro case was a demand for standardized DNA testing to ensure the technology was performed correctly. A "technical working group on DNA methodology" (TWIGDAM) was established by the FBI, who eventually helped standardize DNA testing.

**U.S. v Two Bulls, 1990**

Matthew Sylvester Two Bulls, Jr. was brought to trial and convicted of aggravated sexual abuse and sexual abuse of a minor in United States District Court in South Dakota. In the pre-trial hearing, DNA fingerprint testing was deemed to be generally accepted so they allowed the evidence to be admitted in court. Two Bull's attorneys appealed the case under the pretence that the third prong from *Castro's* Three Prong Test was not addressed. The district court did not determine if the testing procedures used by the FBI laboratory were performed as they should be. The appellate court reversed the decision of the district court, and ruled that the DNA evidence presented should not be admitted to the trial.

In response to this ruling, the government argued that "*Castro* stands alone and provides too stringent a standard, necessitating long drawn out testimonial procedures before trial" (*U.S. v. Two Bulls, 1990*). In addition, they also argued that Rule 702, the 'helpfulness rule,' allows for a more liberal rule to determine admissibility. The court of appeals did not agree with the argument of the prosecution and prevented the DNA evidence from being brought to court.

When determining whether the DNA evidence was admissible, the court of appeals insisted that both *Frye* and Rule 702 require a solid foundation for DNA labs. Both of these tests require the same approach when determining evidence admissibility and the court felt that neither rule should allow testing that is speculative or hypothetical in nature which "fails normal foundational requirements necessary for the admissibility of scientific testimony or opinion." (*U.S. v Two Bulls, 1990*)

The appeals court found that the trial court was wrong when admitting the available DNA evidence without investigating the reliability of the laboratory and its techniques. If the admission of evidence is questionable, the court should hear both sides of the story before a ruling is made. The appeals court sent the case back to the trial court to be re-tried with the addition of an expanded pre-trial hearing where the admissibility issues would be addressed. The court of appeals introduced a new 'Five Prong Test' which stated that the court should decide "(1) whether DNA testing is generally accepted by the scientific community, (2) whether the testing procedures used in this case are generally accepted as reliable if performed properly, (3) whether the test was performed properly in this case, (4) whether the evidence is more prejudicial than probative in this case, and (5) whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under rule 403." (*U.S. v Two Bulls, 1990*) The Two Bulls conviction was remanded to the trial court with directions to conduct an expanded pre-trial hearing on the admissibility of the evidence.

**People v. Miles, 1991**

In the Circuit Court of Vermilion County in Illinois, Reggie E. Miles was convicted of two counts of home invasion, five counts of aggravated criminal sexual assault, one count of criminal sexual assault, one count of aggravated unlawful restraint, one count of armed robbery, and two counts of residential burglary. DNA evidence was collected in this case and allowed in trial aiding the guilty verdict. The case was appealed afterward in the Fourth District Appellate Court of Illinois on August 6, 1991 on the basis that that the DNA testing used was beyond the understanding of the general public.

The appellate court agreed with the lower court's decision in admitting the evidence. They held that "expert testimony is admissible when the expert has knowledge or experience not common to a layman, and this knowledge or experience would aid the jury in determining the facts at issue." The DNA procedure used for identification was beyond the understanding of the general public. The expert witness presented a testimony that was clear and thorough, and also aided in the decision of the jury. The evidence concerning the procedures used in the case did not indicate that the results were clearly or inherently unreliable." (*People v. Miles, 1991*) The defense responded with a cross examination of the prosecution about general DNA testing procedures, and the reliability of those procedures as conducted by Cellmark. Based on the expert testimony, the cross-examination, adequate procedures by Cellmark, and TWIGDAM standards, the court of appeals reinforced the circuit court's decision to permit the DNA evidence in trial, and the guilty verdict stood. At this point, in 1991, the correct path was paved to follow when determining whether to allow DNA evidence in a United States Court Trial.

# CHAPTER 4: SENSATIONAL DNA CASES

The application of DNA evidence in U.S. courts has been illustrated in main stream criminal trials as well. Although such trials may not have set legal precedents for admitting DNA evidence, they are likely where the public first learned of DNA evidence and its power. This chapter looks into a couple of these sensational cases that has brought DNA Fingerprinting to the eyes of the public.

## The Case of the Boston Strangler

Thirteen Boston women were strangled to death in the early 1960's stirring up a fear that was shared by all the residents of the area. There were differing opinions on the identity of the crime doers. The public felt that these despicable deeds were all done at the hand of one man. The investigating police, however, had their doubts. All 13 of these murders seemed tied together with very obvious similarities between each case. All of these crimes were performed within the residence of the victim with no forced sign of entry at all. Each woman was strangled with some article of the victim's clothing, which in several cases, was clothing that the victim herself was wearing. All of the victims had also been sexually molested.

The first of the Boston Strangler's victims, 55 year old Anna E. Slesers, was murdered on the evening of June 14, 1962. When Sleser's son Juris came by later that night to pick her up for a church service, he found no response to his knocking on the door. Juris forced his way into the apartment and found his dead mother on the floor of the bathroom with the tie from her robe wrapped around her neck. The apartment was turned over, yet nothing was taken. The apartment was set up to look like a burglary gone wrong. Sleser was also found to have been sexually abused. (*Bardsley & Bell, 2003; Gardner, 1964*)

Less than 3 weeks later (June 30th), two more women were victimized. Sixty-eight year old Nina Nichols was found with two of her nylon stockings tied around her neck into a bow, and her dead body had signs of sexual assault Her Brighton apartment on Commonwealth Ave. was ravaged but nothing was taken. Over fifteen miles north of this scene, in Lynn, Massachusetts, Helen Blake was also strangled with nylons this same day. Just as in the other apartments, the apartment was ransacked and the women were abused sexually. This time, on the other hand, the killer left with two of Blake's rings that she wore on her fingers. A metal strong box and footlocker belonging to the victim were found to be worked on and attempted to be broken into. (*Bardsley & Bell, 2003; Gardner, 1964*)

These murders worried the police force, and the women of the crime areas and surrounding areas were warned to make sure to lock their doors at night and to not let anyone in. The public was alerted that there was a danger of stranglers around. Boston turned all of its eyes to this case and worked ruthlessly on breaking it. Every sex offender that the police knew of was interviewed and put under a microscope. Seminars for detectives were set up by the FBI to teach how to deal with sex crimes.

A couple more weeks went by, and the Boston Strangler emerges again with his fourth and fifth acts. On August 19, seventy-five year old Ida Irga was choked, sexually abused, and left in front of the doorway in her living room of her Grove Ave. apartment in the West End. Across town, in Dorchester, Jane Sullivan, 68, was executed with her nylons and left dead in her bathtub. She wasn't found for 10 days. In both of these cases, no signs of forced entry were found, though, these apartments were not torn apart as the previous ones were. (*Bardsley & Bell, 2003; Gardner, 1964*)

Months went by where the women of Boston lived in fear for their lives. This unsettling feeling sat in their stomachs without any murders happening. No more murders took place until December 5, when a twenty-one year old girl was killed in her Huntington Ave. apartment. Sophie Clark was strangled with her nylons blocks from the apartment of the first victim Anna Slesers. The Boston Strangler had switched his aim to a younger and more alluring victim. Clark was the first of a new series of younger victims of the Boston Strangler. (*Bardsley & Bell, 2003; Gardner, 1964*)

A few more months went by and in early March, Mary Brown of Lawrence, Massachusetts was found beaten, strangled and raped in her apartment. Mary Brown was sixty-eight years old. Shortly after that, a twenty-three year old graduate student became the next victim. Mary Brown was found with her hands tied behind her, nylons tied around her neck, and multiple stab wounds. Oddly enough, the nylons in this case were not the cause of death in this incident. In fact, the nylons were not even tied tight enough around her neck to have killed her. Brown was stabbed twenty-two times; the four fatal stab wounds were in her neck, the other eighteen, in her chest. Brown, unlike the other cases did not seem to have been sexually assaulted. (*Bardsley & Bell, 2003; Gardner, 1964*)

The police, frustrated with not getting anywhere in the case, called upon a self-claimed ESP visionary named Paul Gordon. After speaking with police, Gordon revealed accurate details of the cases and named Arnold Wallace as the alleged killer from a photo.

The police investigated Arnold and found that he had been placed into mental hospital. However, the police also found out that Arnold had escaped from this hospital on the same days as the murders took place. Although, it was also discovered that Paul Gordon, the psychic, had been to the hospital before he talked with the detectives, and he could have sought a patient whose release hours matched the killings, whether he committed them or not. Because of this, there was possibility that this whole thing was a hoax, so Wallace was returned to the hospital and re-admitted for treatment after they conducted a worthless lie detector test.

All was quiet again for sometime until the summer of 1963 when the life of fifty-eight year old Evelyn Corbin of Salem, Massachusetts was ended when nylons were tied around her neck. Her jewelry box was found open on the floor and her purse was ruffled through on the bed, however, nothing was stolen.

On November 25, three days after JFK was shot, Joann Graff became another one of the strangler's murders. Graff, just like the other homicides, was killed with her stockings and was sexually assaulted. Teeth marks were found on her breast during examination. This case however is a little different than the other cases in that the killer may have been seen. At approximately 3:30 am, a student that lived upstairs from Graff heard knocking on the door across the hall. He opened his door to speak with the gentleman. A young man of about thirty years old asked him, "Does Joan Graff live here?" The man mispronounced her name, and at the time, the student did not find it suspicious. Moments later, someone entered the residence of Joann Graff and ended her life. (*Bardsley & Bell, 2003; Gardner, 1964*)

The last of the Boston Strangler's strikes occurred in January of 1964, over a year and a half from the first attack. Nineteen year old Mary Sullivan was strangled with her nylons in her apartment and left for her roommates to find. She was presented in a manipulated way, where a pink scarf was tied around her neck over the stockings and she was placed in a seated position on the bed. There were blatant signs of sexual abuse present and the killer left behind a "Happy New Years" card leaning against Mary's foot. (*Bardsley & Bell, 2003; Gardner, 1964*)

The case of the Boston Strangler was taken over by Massachusetts Attorney General Edward Brook on January 17, 1964. Brook started a special task force for this case called the Special Division of Crime Research and Detection. The case was spread over 5 different jurisdictions, and the activities of the departments involved were coordinated by this task force. Instead of each department having their own information pertaining to the case and not sharing it with the other departments that it might help, the SDCRD hired a permanent staff that only worked on these cases and kept all the information for them. Brooke chose Assistant Attorney General John S. Bottomly to lead the group. The group never arrested or tried any suspects to these murders; in fact, the group never developed any suspects at all. It wasn't until a man confessed to another unrelated string of sexual assaults, that a controversial closing to this case was seen as possible. At least the special division provided a certain comfort for the public in such a dreadful time. (*Bardsley & Bell, 2003*)

Two years prior to the Boston Strangler murders, a different series of sexual assaults was rampant in Cambridge. Albert Desalvo, 29 years old with a family, was arrested for these crimes. Desalvo resided with his German wife Irmgard Beck and their two children in Malden, Massachusetts. Desalvo was the product of what could be called a broken family. When Albert was younger, his father abused him and he spent a lot of time getting into trouble. He enlisted in the army in 1948 and was stationed in Germany where he met his wife. Eight years later, Albert received an honorable discharge after disobeying orders of a higher officer and being demoted to private. He was arrested for fondling a young girl in 1955, and in that same year his wife had a baby girl. Judy, Desalvo's baby daughter, was born with a physical handicap which discouraged Desalvo's wife from having another child. Albert's wife, afraid to get pregnant again, refused to have sexual relations with her husband, who reportedly had a strong sexual appetite.

On October 27, 1964, a woman awoke to find a strange man in her home. With her husband away at work, the woman was sleeping alone. The man that entered the house, laid down with the woman and then started kissing and feeling her up. Then, after apologizing, the man told her to be quiet and left. The woman went to the authorities and provided them with details to compile a sketch. The police recognized this suspect as a man that they had linked to other cases, coined the "Measuring Man." (*Bardsley & Bell, 2003*)

This Measuring Man was a pervert who posed as somebody from a modeling agency. The man would go door to door, knocking and enticing women to let him in. He would say that he worked for a modeling agency and wanted to take measurements. After 'measuring' the women, he would tell them that a "Mrs. Lewis" would contact them. This would never happen, and eventually, women started complaining. On March 17, 1961, police caught a man breaking into a house in Cambridge. The man they caught, Albert

Desalvo, confessed to the breaking an entering, and also to be the Measuring Man they had been looking for.

After the sketch of him was produced in the case in October of 1964, Albert Desalvo was brought in for questioning. Desalvo had only served an 18 month sentence for the Measuring Man incidents when he was brought in for the recent sexual attack. The attack victim positively identified Desalvo as the man that was in her home on the night of the attack. Desalvo was released on bail and roamed free again until he was arrested again for another string of sexual attacks a short time later. This string of attacks occurred in Connecticut where authorities were looking for the 'Green Man' a name coined because the attacker wore green pants in all the incidents. Desalvo confessed to over 400 breaking and entering incidents, 300 assaults in 4 states, and several rapes. Since Desalvo enjoyed bragging and not all of these incidents were reported, none of these figures are actually confirmed. Desalvo was sent to Bridgewater State Hospital. (*Bardsley & Bell, 2003*)

In his time at Bridgewater State Hospital, Desalvo became friendly with his ward-mate, George Nassar. Nassar was very smart as well as manipulative. Nassar was sent to the hospital after being arrested for executing a gas station worker. It is believed that in their time together, Desalvo and Nassar worked out a plan where Desalvo would confess to being the Boston Strangler and that the reward money Nassar received for turning him in would be split between the two. Desalvo understood that he would probably spend the rest of his life behind bars, but he thought that the money they could get from the publicity of the case through books and interviews would really help his family. (*Bardsley & Bell, 2003*)

Thus, on March 6, 1965, Desalvo confessed to be the man behind the Boston Strangler murders. George Nassar's lawyer, F. Lee Bailey was the one who taped the confession from Desalvo. In the recording, Bailey asks Desalvo what he wants from him. Desalvo said, "I know I'm going to have to spend the rest of my life locked up somewhere. I just hope it's a hospital, and not a hole like this. But if I could tell my story to somebody who could write it, maybe I could make some money for my family." (*Bardsley & Bell, 2003*) Commissioner McNamara and the psychiatrist at Bridgewater State Hospital became involved. Baily convinced Desalvo to take a lie detector test and to submit to questioning about the murders. Everyone became convinced that Desalvo was indeed the Boston Stranger after 50 hours of taped conversations and 2,000 pages of transcript were produced on or around September 29, 1985. (*Bardsley & Bell, 2003*)

Not everyone, however, believed that Desalvo really was the Boston Strangler. Those close to Desalvo, his family, friends and former-coworkers did not believe that Desalvo would ever commit these disgusting acts. They believed Desalvo to be a kind and gentle man, not capable of murder. (*Lavoie, 2003*) In her book *The Boston Strangler: The Public Conviction of Albert Desalvo and the True Story of Eleven Shocking Murders*, Susan Kelly laid out many reasons that she believes Desalvo to be innocent. One of the main reasons for her argument was that there was no physical evidence that linked Desalvo to any of the murders. A secondary reason was that Desalvo was not identified as the murderer by any of the eyewitnesses that supposedly saw the stranger involved. Kenneth Rowe, the student that lived above Joann Graff, was shown a picture of Desalvo and could not tell if he was indeed the man he saw knocking on doors. Eileen O'Neil, who saw a man in Mary Sullivan's bathroom, also said that the man in the photo was not the same man she had saw in person. A third reason Kelly based her stance on was the presence of cigarette butts at the scene of Mary Sullivan's death. An ashtray was found near Mary's bed that contained a cigarette brand that no one at that residence smoked. Desalvo didn't smoke cigarettes at all. A butt from the same brand cigarette was also found in Sophie Clark's toilet. Two witnesses were brought to identify Desalvo posed as visitors to the hospital. One of these witnesses, Marcella Lulka lived in the same building as Sophie Clark and had encountered the man, who introduced himself as Mr. Thompson stating that he was there to paint. The other witness was Gertrude Gruen, a survivor of a Strangler Attack. These women went to the visitor's area of the hospital to wait to see Desalvo. When George Nassar entered, however, Greun became startled and uneasy. When Desalvo entered, Gruen positively excluded Desalvo from being her attacker. Later on, Gruen let the police know that Nassar reminded her very much of the man who attacker her.

Dr. Robey, the psychiatrist at the hospital, testified that Desalvo had a remarkable memory. Since the newspaper accounts of the crimes were very detailed, it was very possible that Desalvo just knew about the details of the crimes. It is also reported that Desalvo may have visited the crime scenes after the crimes which could have given him a good visual layout of the home. The remaining details of the case could have been passed on by Nassar in their time together in the hospital. A final piece of evidence arguing that Desalvo was not the Boston Strangler is that the police as well as many experts believed these crimes to be done by more than one individual. The modi operani was not the same in all the cases as was common of serial killers at that time. The style of serial murders were not very often dynamic, the murderer usually had one style and kept with it. (*Kelly, 2002*)

The public was content with holding Desalvo to the crimes of the Boston Strangler. After being found competent to stand trial, Desalvo went to trial on January 10, 1967. Desalvo was found guilty for the Green Man incidents and was sentenced to life in prison. While serving life at Walpole State Prison, Desalvo died in November of 1973 after being stabbed multiple times. Shortly before this, however, he contacted Dr. Robey to meet with him. Desalvo claimed that he would reveal the true story of the Boston Strangler. The night before his meeting with Robey, Desalvo was killed. It is believed that Desalvo was involved in a drug operation that led to his death. (*Lavoie, 2003*)

More recently, in 2001, DNA forensics has been applied to the case. The body of Delsavo was exhumed for autopsy, and the body of the last victim Mary Sullivan was found to have the presence of two DNA samples that were neither Mary Sullivan's nor Albert Desalvo's. This DNA testing was done at the hands of Professor James E. Starrs at George Washington University on December 13, 2001. (*Bardsley & Bell*) Currently there is no sample for Nassar's DNA, and no solid evidence otherwise to associate him with the Boston Strangler.

**The Trial of Orenthal James Simpson**

In the early morning of June 25, 1994, Los Angeles resident Sukru Boztepe was awakened by a barking dog which she found blood on. Boztepe became alarmed and investigated the residence of the neighbor, the owner of the dog, Nicole Brown Simpson. There she found the aftermath of the horrible murder of Nicole Brown Simpson and Ronald Goldman, 25. The murder took place sometime before ten o'clock on Sunday night, June 24, 1994. It is alleged that Goldman was at Nicole's house to return a pair of sunglasses left by her mother at the restaurant where he waited tables. Police responded to a call that resulted in an investigation and the longest jury trial in California history.

Several pieces of evidence at the scene pointed to Orenthal James Simpson, celebrity, football star and ex-husband of one of the victims, Nicole Brown Simpson. Several blood samples were found that indicated that O.J. was involved with the murder. Drops of blood were found on the ground near a shoe print, which was matched to a size 12 pair of Bruno Magli shoes, and in a white Bronco that belonged to O.J., as well as in the driveway, foyer and master bedroom of his home. Among the stated pieces of evidence, there was also a notorious pair of gloves involved. The pair of gloves was an extra large pair of Aris Light gloves. The left glove was found at the scene, and the right glove, with blood on it, was found at Simpson's home.

On the night of the murders, O.J. Simpson boarded American Airlines flight 668 from Los Angeles to Chicago. A Town and Country limousine, driven by Allen Park, picked him up at his home and drove him to the airport at approximately 11 pm. Later on, Part testified that he attempted to pick up Simpson at 10:30 but nobody answered the door at his house. When O.J. arrived in Chicago, he checked into O'Hare Plaza Hotel. He was planning to attend a Hertz rental car convention for which he was spokesperson. Simpson was contacted by the police at the hotel the next morning. He asked no questions when informed of his ex-wife's death. (*Linder, 2000a*)

Simpson was on the next flight back to Los Angeles after that call. He was interrogated by police for about a half an hour. They asked him about the cut on his right hand, which he claimed to not remember the origin of. However, later on, Simpson said that it was possibly cut on the Bronco when he reached into it on the night of the murders, and then re-injured at the hotel when he broke his glass. O.J. claimed that he broke a glass at the hotel when he was told of Nicole's murder. This interview was not considered very helpful to either the defense or the prosecution so it was left out of the trial. (*Linder, 2000a*)

After police found and gathered enough evidence, they indicted Simpson for the murders. Forensic serologists from the California Department of Justice alongside a private contractor collected blood samples and those samples were then DNA tested. The blood samples did not match either of the two victims. It was determined that the blood samples found were, with a one in 57 million exception, from O.J. Simpson. The shoe print found was also matched to the shoes worn by Simpson. The gloves found were found to be the same type as ones bought by Nicole in 1990 and worn by O.J. from 1990 to 1994. The police were able to use this evidence to indict O.J. of Nicole and Goldman's murders. (*Linder, 2000a*)

Simpson's lawyer, Robert Shapiro, cut a deal with the police to turn himself in before 10:00 on June 17, 1994, the day of Nicole's funeral. When ten in the morning came around, Simpson was nowhere to be found. Police went to Simpson's home to take him in and found what appeared to be a suicide letter. Several hours later, at about 6:20 pm, a motorist in Orange County called in to police that he had seen Simpson driving in a White Bronco. At the time, Simpson was with his friend A.C. Cowlings. Simpson began a slow speed police chase that called in both ground and air support. The incident ended at Simpson's home, where he was arrested. Police searched his vehicle and found $8,750 in cash, a fake beard and moustache, a loaded gun, and a passport. O.J. was arraigned in court on July 22, 1994 where he entered the following plea: "Absolutely one-hundred percent not guilty, Your Honor." (*Linder, 2000a*)

O.J. Simpson's trial began on January 24, 1995. The initial argument of the prosecution, as presented by Christopher Darden and Marcia Clark, portrayed Simpson as an abusive father, as well as being very jealous of his ex-wife and lover, Nicole. Their aim with this argument was to make it conceivable that Simpson could have killed Nicole just so she couldn't be with anyone else. After they painted the picture they wanted depicting Simpson, they laid out the facts they had collected against him. They were going to prove that O.J. was in fact the murderer of Nicole Brown Simpson and Ronald Goldman. (*Linder, 2000a*)

The next day in his opening statement, Jonnie Cochran stated in Simpson's defense that he was going to prove that the evidence that was collected against Simpson was "contaminated, compromised, and ultimately corrupted." (*Linder, 2000a*) Cochran presented a timeline that was very confusing and suggested that due to his arthritis, it was impossible for him to have committed the double homicide. The prosecution followed by presenting a timeline for the night of the crime that indicated that Simpson had plenty of time to kill Nicole and Goldman, and also was likely to have done so. Over 99 days, the prosecution presented 72 witnesses proving Simpson's abusive behavior.

The first people to be called to the stand to prove Simpson's abusive behavior were the family and friends of Nicole and Orenthal. Nicole's sister, Denise Brown testified that on several occasions she witnessed Simpson demonstrating abusive behavior toward Nicole. She claimed that she saw O.J. earlier that day and he looked like a "madman." Ron Shipp, a close friend of Simpson, testified that Simpson confided in him that he had recently had dreams of killing Nicole. Also brought to the stand was a 9-1-1 operator who had once answered a call from Nicole. In the tape played in court, Nicole calls 9-1-1 to report spousal abuse, while her yelling and swearing husband (O.J.) is heard in the background. (*Linder, 2000a*)

The prosecution next attempted to elaborate on the timeline of the night. The first Witness called was Allen Park, the limo driver who drove Simpson to the airport on the night of the murder. Park began that he was supposed to pick up Simpson at 10:30. He arrived at the residence at 10:25 pm, went to the door, and rang the bell over and over again. No one answered the doorbell so Park returned to his limo and waited until about 11. At this time, Park saw a tall dark figure of about 200 pounds walk into Simpson's residence. Moments later, Simpson came to the door, apologized to Park and offered the explanation that he had overslept. Simpson was carrying a black bag with him which he refused Park from touching. (*Linder 2000a, 2000b*)

The next witness that was called to the stand to help piece together the night was Kato Kaelin. Kaelin was Simpson's houseguest on the night in question. According to Kaelin, Simpson and he went to McDonalds that night and returned to the house at 9:36 pm. Charles Cale, Simpson's neighbor, was able to testify that between 9:30 pm and 9:45 pm, he was walking his dog near Simpson's home and did not see his white Bronco there. Allen Park was in front of Simpson's house before 10:30 and waited there until about 11:00 pm when Simpson came out and got in the limo. (*Linder, 2000b*)

The final set of witnesses testified in regards to the physical evidence. The technical evidence collected consisted of blood, hair, fiber, and shoe print analysis. The blood specimens were subjected to two DNA tests called RFLP's. These tests showed that the blood found at the scene matched Simpson, and that only 1 person in 170 million could produce such a match. Blood spots found on Simpson's socks at home were shown to be that of Nicole, and that only 1 person in 6.8 billion could produce such a match. The defense tried to suggest that the blood spots found at Simpson's home were either contaminated or planted by the police. Detective Mark Furman was called forward by the prosecution in order to testify that the evidence could not have been planted. The defense argued that the witness was likely to have planted the evidence because he was racist. The defense asked Furman if he had ever used the 'n-word', Furman lied and said no. This was used against him to prove that he was racist, and thus likely to have planted evidence. (*Linder, 2000a*)

The next evidence presented to the court was the relevance of the bloody gloves found at both the scene and at Simpson's house. The prosecution presented one of the gloves to Simpson and asked him to try it on. When he obliged, the glove did not fit on his hand. Whether the glove had shrunk or his hand had swelled, the jurors saw Simpson attempt to try on a glove that did not fit. The prosecution also presented evidence that Simpson's hairs were found in a hat at the scene that were also consistent with those on Goldman's shirt. There was also evidence of cotton fibers found on the glove at Simpson's home that matched those on the carpet of Simpson's Bronco and on the hat at the scene. (*Linder, 2000a*)

The defense called more witnesses to disprove the prosecution's claims in regard to motive, to show that Simpson was incompetent to commit the crime, show that the timeline presented by the prosecution was inconsistent and flawed, and show that the technical evidence collected at the scene was contaminated, planted or both. Simpson's daughter, mother, and sister all testified as character witnesses. Simpson's doctor testified that Simpson was not in good health despite how he appeared. The prosecution replied with a video showing Simpson physically active which showed that he was in better shape than he let on to his doctors. The defense presented two more key witnesses in the case. The first of which was a screenwriter named Laura Hart McKinny. She testified that in interviews and tapes recordings between herself and Furman for her work, that Furman excessively used the 'n-word' and even admitted to planting evidence to guarantee convictions in the past. Furman was presented as a racist. The other key witness in the case was Dr. Henry Lee, a criminologist with good credentials. Lee testified that he believed that there was "something wrong" with the conclusions of the DNA tests presented by the prosecution. He argued that the way the blood was packaged could have compromised the sample. This helped the defense argue that the samples were switched because the originals were degraded because they were stored in a lab truck. The prosecution countered by saying that the samples could not have degraded enough to prohibit accurate analysis. Their testing measures provide indications for any contaminations as well. The defense retorted that the lab had mishandled the controls.

In closing arguments, the prosecution tried to demonstrate that there was no frame up, despite Furman being racist. The jury was then presented with the large pile of evidence by Marcia Clark. The defense used the aspect of Furman's racism to manifest the possibility that the evidence was planted. The jury deliberated for four hours and concluded that Simpson was not guilty. After the criminal trial, Simpson was brought back to court in a Santa Monica civil trial. In this case judged on the preponderance of evidence, not beyond all doubt, the Judge called Simpson forward to testify and disallowed the defense to present theories similar to that in the criminal trial. The jury deliberated for 17 hours and after using the “preponderance of evidence” that is valid in civil trial, found Simpson guilty of the wrongful deaths of Nicole Brown Simpson and Ronald Goldman. (*Linder, 2000a*)

# CHAPTER-5:  DNA DATABASES

In the courtroom today, new developments allow judges and jurors to more accurately convict criminals of crimes and release innocent people from false convictions. In the past, if there were no witnesses to the crime one of the only ways one could place a criminal at the crime scene was to find that person's fingerprints at the scene.  Within the past 20 years DNA evidence has become the new forensic standard.  Finding drops of bodily fluid or hair became a sure thing to lead to convictions.  Although this method is usually accurate, sometimes it can be misleading if a person just happens to have similar DNA to another person.  To rule out these misleading cases, over the years techniques have been developed to prevent mismatches to non-related DNA.  New DNA loci were identified that showed greater variability in the human population, and more loci were analyzed per sample. And most importantly, DNA databases were established to 1) allow cold hits to previous offenders, and 2) help establish more accurate DNA probabilities for each locus analyzed.

CODIS (combined DNA index system), the FBI's DNA database has become the world's largest.  This database links community, state, and national databases, with each state establishing who is required to donate DNA  The more people placed into these databases, the more accurate the frequencies of each DNA locus can be determined in the human population, which increases the accuracy of the technique.  The more accurate the data, the greater likelihood the courtroom will accept the data.  This will help decrease the number of falsely convicted people every year and help in the search of possible suspects. Many people ask, what is a DNA database, why do we need them, and won't it interfere with our right to privacy? People should be concerned about these issues, but should also be informed about what is going on with these situations in our nation and in our states.

British scientist Alec Jeffrerys was the first to perfect the identification of unique markers from DNA samples. In 1986 the first DNA samples were used in tracking down the rapist of two young girls in a small town in great Brittan. Samples were taken from 4,000 men in this town and neighboring towns until the man was found and convicted. Since then Britain has created a comprehensive DNA database with more than 3 million samples of convicted criminals in their system.

Following the trend of Great Britain, the United States passed a bill creating CODIS. CODIS, which stands for Combined DNA Index System, operates on three levels which are: the local (LDIS), where most of the DNA samples are collected, the state (SDIS), and finally the national (NDIS) ("CODIS Combined…2004). In CODIS there are also two indexes one for convicted felons, based on what state legislature decides what crimes are bad enough that the convicted felon needs to give a DNA sample. The other is for the forensic data collected at different crime scenes. The forensic index is used mostly to link other crimes together through similar DNA samples being found at each crime scene. This system allows local, state, and national law enforcement to coordinate their investigations. Since the early 90's when CODIS began it has aided in more than 25,400 investigations, and as the database increases it will be able to aid more cases each year. In the court room what is the most concern is the probability of a match in a crime or the probability that it could be someone else's DNA.

A DNA database is a collection of genetic information taken from a small strand of our DNA helix which slightly differs from one individual to another. To prove a suspect's

DNA matches the DNA left at the crime scene two main things need to be addressed. There first needs to be the creation of a DNA profile using molecular biology protocols. This procedure establishes what type of DNA you have at specific points in the DNA molecule. The currently accepted protocol analyzes 13 core loci. Once this is done you need to get percentages of occurrences of each locus in a given population, using the principals of population genetics (Brenner, 2004).

All you need to look at is about three or four loci to get a low (1 in 7000) percentage of making a false match. This is what is called a random match probability, the chance that a DNA profile will match another unrelated sample. When a low percentage is found, this tells you that either the suspect produced the evidence, or there is a random 1 in 7000 chance that another person would have the same DNA as obtained with the evidence. To know that the arrested suspect matches the profile from a crime scene sample is sometimes enough evidence to convict him even with no other evidence provided. Possibilities for someone else leaving the DNA evidence might include if he claims it was an identical brother, DNA contamination, or if an error was performed with the technique (Brenner, 2004).

**Databases and Privacy Rights**

Whose DNA should be included in the CODIS system? Currently, each state has the right to make that decision. Most states currently require persons convicted of violent felonies and some violent misdemeanors to provide a DNA sample. But many people have varying opinion on the matter of DNA database expansion, whether to include more criminals of lesser offences even if they are not convicted (i.e. arrested persons). People in favor of mandating all arrested persons to provide DNA argue the more DNA in the database, the greater likelihood of catching criminals with cold hits to crime scene samples. And, afterall, all persons arrested are required to provide their regular fingerprints, whether they want to or not.

Others are against expanding who is required to provide DNA samples. When testifying before congress, the Director of the American Civil Liberties Union's Technology and Liberty Program said that while DNA databases may be useful to identify criminals "I am skeptical that we will ward off the temptations to expand their use". He goes on further to say that such mandatory sampling of suspects and felons changes the way the government treats its citizens (Rosen, 2004). This is like the government turning its back on the rehabilitation of criminals, saying that because you were a danger in the past you will be in the future, so we will keep you on record. Our country tries to give us freedoms yet at the same time they want to view each person as a crime suspect.

Proponents of civil liberties argue that our government is heading toward a time where it can just take anyone's DNA without question, giving the power to be able to see your future health, where you have been, and even the characteristics of your family. What most people don't realize is you can not determine medical predispositions from the type of evidence placed in a forensic database like CODIS. All that is placed there is the length of some "junk" DNA sequences analyzed because of their uniqueness. Thus so long as the original DNA sample is destroyed, no medical information can be obtained on any felon, or innocent donor. Laws need to be passed to ensure the original sample is destroyed, regardless of who donated it.

Right now more than 30 states collect DNA evidence from juvenile offenders who may or may not be convicted of a felony. These offenders range in age anywhere from 8 to 17 and have had a felony charge put against them. In 2005 the violence against women act helped the government to add more to their DNA database by requiring all people arrested for a violent crime to submit a DNA sample regardless of weather or not they are convicted. Some argue this is a complete violation of the fourth amendment to the constitution which prevents the government from unlawful search and seizure. Although the DNA sample is removed from the CODIS system if the person is eventually found innocent, the DNA sample still remains in the hands of the state and local government forever, so new laws need to be passed requiring its destruction.

Many complex issues are brought forth by this new collection of genetic information from people. The majority of these issues are based upon the people in charge of this information and what they can and can't do with the information, and whether this DNA sample can or should be taken from an individual. What rights do we have when it comes to our unique genetic information? In Iceland a company named Decode, headed by an ex-M.I.T. Professor, bought the right to the country's genetic information. This information is valuable to the company because of the small genetic pool from which most of the population was derived has carried down through the ages on the small island. Since so much of the genetic information is similar to what it has been for many thousands of years it is easier to see defects in the genes and hopefully it will help in the treatment of genetic diseases. But does any country really have the right to sell their people's genetic code, and who should be able to obtain this information? Many insurance companies would love to get their hands on information of this sort to tell how this person will be affected by their genes later in life. So again regarding DNA databases, it is important to note the difference between a medical or genetic database, like what is done in efforts to cure cancer, versus a forensic database which is composed of no medical information.

There now is a conflict between the good of studying genetics for the causes of disease and the rights of the individuals who supplied the information for the tests. To allow the benefits of this gene testing while maintain the rights of the citizens will require new legislation at the state and federal level. This legislation would be to stop genetic discrimination. Genetic discrimination will arise from the knowledge that population testing will reveal concerning different groups of people and the risk they have for genetic problems. So for example, certain individuals could be denied life insurance if they possess a certain genetic predisposition. This will further instigate racial issues and discrimination of certain races due to their genetics.

This type of DNA genetic discrimination has already occurred in our country as early as the 1970's. In 1972 congress passed the sickle cell anemia control act. Since African Americans are more likely to carry the sickle cell trait, discrimination occurred after state wide screening found a correlation of a genotype with the trait. Insurance companies stopped covering people who carried the trait for sickle cell, even if they presented no symptoms, and the Air Force expelled many pilots for also carrying the trait. These issues lasted until someone sued the Air Force for their expulsion on the grounds that carrying the trait for sickle cell anemia doesn't affect stress on the body in low oxygen levels in high altitudes (Sasjack, 2002).

Discrimination will only continue to occur when more genetic evidence is found over time for all groups of people. Education is another answer to these social problems regarding genetic issues. People need to know what it means to be a carrier for a disease, and just because you are not a carrier or at risk it doesn't mean you won't contract the disease. Many people today perceive genetic testing to be a risk to them which is a main reason why it is so hard to get population genetic testing, or any genetic testing. Yet another hold back of genetic testing is the shear cost of it, and its inaccuracy. It costs more than $2,000 just to test for mutations in two genes which could cause breast and colon cancer. Most people don't want insurance companies to cover these tests or even know about them, so they have to pay out of their pocket.

Regardless of our population's lack of knowledge about no medical information being present in forensic databases, they continue to blur the key distinction between forensic databases and genetic databases. And concerning sample collection, they fear eventually being listed in an FBI database without conviction even though only a few states are even considering switching to allowing this. The government under the Bush administration continues to push toward the setup of the national database by putting one billion dollars to aid in the progress of this database.

The people that will have to deal with these issues of the DNA database are the politicians. They are the ones who hear stories of convictions in cold cases and the freeing of innocent men. They are also the ones who control legislation on these issues. So in a way we have some control over what happens in the future through voting and writing letters to congress pushing them one way or another on the legislation regarding DNA databases in each state. Although this testing is so useful, state governments need to ensure that people's rights are not violated. These laws should be focused on the destruction of DNA samples taken from convicted violent felons who are later found innocent or released. This way the information can not be used against an innocent person. Along with this law there should also be continued research into identifying unique DNA loci to use for analysis to help ensure the greatest probability of matches, and laws regulating the collection and handling of DNA samples to ensure samples are not contaminated or misused.

The world's medical, legal, and scientific future all rest upon the genes in our very bodies. Although good for our well-being and elimination of certain genetic diseases/disorders, this information threatens to change they way our government regulates what we do and how we look at life knowing our medical future. Law makers over the next few years are going to have to find a happy medium expanding genetic studies but also strongly guarding the rights of the citizens. Discriminations could occur in the way of stereotyping a certain group, or denying employment and insurance coverage. The CODIS database in the United States is the world's largest collection of DNA profiles. Having criminal's DNA profiles contained in this database is an excellent way of tracking and keeping records of convicted felons, but the law must control whose samples goes into these databases. They must block states from a mandatory collection of DNA samples from arrested suspects, and destroy DNA samples from convicted criminals after the non-medical forensic profile is entered in the database.

# CONCLUSION

A DNA fingerprint or profile examines minute differences in the DNA sequences between individuals. The analysis creates a pattern that is unique to everyone. This is technically hard to do since 99.9% of human DNA is common to all people. DNA fingerprinting can be used for many different applications in today's scientific world. It can be used in paternity cases to prove the relation of a child to his or her father or mother. Another application is in Molecular Archeology in which scientists can test ancient DNA samples to more accurately determine the age and origin of a particular biological sample collected from the earth. It can also be used to trace the roots of our ancestors. DNA fingerprinting is also a key in many of today's court cases and in the future of medicine regarding genetic diseases.

There is more than one way to obtain a DNA fingerprint. Some of the more common ways were described in Chapter-1, and include Restraction Fragment length Polymorphisms (RFLPs), Variable Number of Tandem Repeats (VNTR), Short Tandem Repeats (STR), and Polymerase Chain Reactions (PCR). RFLP is a technique that analyzes the differences in lengths of DNA bands between specific restriction sites in the DNA molecule. Because this technique does not amplify the DNA, fairly large samles are required for analysis compared to STR/PCRs. VNTR sites are the most frequently examined sites by RFLP since they represent different numbers of tandem repeat sequences between individuals. These sites are often too long to analyze by PCR, so again large amounts of material are required. PCR analysis of STR loci is currently the most widely used method due to its ability to amplify the DNA from very small samples. STR's are sites whose lengths of tandem repeats vary but they are short enough to be amplified by PCR. So the STR/PCR technique can be performed on small amounts of material, and the analysis avoids the rigors of probe hybridization required for RFLPs/VNTRs.

New technologies call for new techniques and procedures. Collecting DNA evidence calls for a highly stringent policies since improperly collected evidence can be thrown out as evidence in a trial, as the world learned in the OJ Simpson case. This requires a proper training to all who could potentially be called to investigate a crime. This topic was presented in Chapter-2. Investigators as well as regular police must know how to properly secure a crime scene and collect evidence. This will ensure a complete and accurate view of the crime scene. Investigators must know how to store evidence to keep it intact, and to properly describe its place at the scene when collected. For instance, when collecting DNA evidence, paper bags must be used not plastic to avoid moisture which can degrade DNA.

After evidence is collected it is very important that it is well labeled and correctly stored. Liquid samples must be stored at below freezing temperature to ensure lack of DNA degradation. All other evidence can be kept at room temperature or slightly below that. Keeping evidence rooms free of moisture is equally important as it is the number one degrader of DNA samples over time.

Getting DNA evidence accepted in U.S. courts was not an easy task until quite recently. Chapter-3 discussed several landmark DNA court cases that helped establish precedence for accepting DNA evidence. These DNA landmark cases in turn relied on previous cases for accepting non-DNA technical evidence in courts. The outcome of these landmark cases was the establishment of a series of “prongs” or tests to be discussed in pre-trial hearings to determine whether the DNA collection and analysis was performed correctly prior to allowing it in a particular trial.

The public often is unaware of these landmark cases, but instead learns of the power of DNA fingerprinting from sensational cases. These cases, discussed in Chapter-4, were widely publicized and are still talked about today, such as the case of the Boston Strangler, and the O.J. Simpson trial. In the original case of the Boston strangler, DNA evidence was not used since the trial occurred before DNA technology was available. However recently DNA evidence was recovered from the last victim of the strangler and determined not to match the person who "admitted" to performing these acts.

In the case of O.J. Simpson, DNA evidence is what ruined the prosecution's case against him. Although there was so much evidence at the crime scene showing that O.J was there the night of the crime, it was shown to the court by the defense that this information was improperly collected and therefore could have been planted or possibly contaminated. This installed possible doubt in the jurors, who declared OJ "not guilty". This trial helped to increase the standards by which DNA evidence is collected and handled today.

The expansion of DNA testing throughout the 1980's and 1990's created a need for a national database of DNA samples. The first to do so for the purposes of law enforcement was Great Britain. Following their creation of a national database, the United States developed CODIS (Combined DNA Index System). CODIS works in all levels of law enforcement from local to state and then federal. Any branch of law enforcement can place the DNA profile of a convicted or non convicted felon, depending upon that state's laws, in this database and can compare a suspect's profile to crime scene samples. This often works well in cold cases where there is crime scene evidence but there is no traditional leads to offenders. These databases also can help in cases where a person is falsely convicted, and DNA evidence collected from the crime scene does not match the suspect.

Although this database system is very helpful in court, ethical questions arise as to whose DNA profiles should be entered in the database. This topic is discussed in detail in Chapter-5. Currently state laws regulate who is required to provide a DNA sample. Most states currently require individuals convicted of violent crimes to provide a sample, however a few states require all arrested persons to give DNA. Many feel the latter stance violates privacy rights. The research performed for this IQP indicates there is a strong difference between medical databases and forensic databases. The latter do not contain any medical predisposition data, but it is extremely important to support laws requiring the destruction of the original DNA sample once the forensic information has been entered into the database to prevent the possibility of obtaining medical data from the DNA stored sample at a later time. Members of the American Civil Liberties group have testified before congress many times voicing their opinions against arrested people being placed in the CODIS system. The job of making sure our rights are not violated falls upon law makers in each state and in congress.

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