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DNA FINGERPRINTING

An Interactive Qualifying Project Report

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By:

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John Hyde

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Prof. David S. Adams, PhD
WPI Project Advisor

ABSTRACT

The purpose of this IQP was to investigate the topic of DNA fingerprinting as an example of the effects of technology on society. The goal was accomplished by investigating the proper techniques for collecting and storing DNA evidence from crime scenes to prevent contamination and degradation, and by describing several landmark court cases that helped set standards for determining whether DNA evidence can be accepted in court. The author provides his own conclusions based on his research.

TABLE OF CONTENTS

PROJECT OBJECTIVES

One of the purposes of WPI's IQP program is to examine the impact of technology on society. The purpose of this project was to examine the topic of DNA fingerprinting as an example project in this societal impact area. The goal of Chapter-1 was to document the proper methods for collecting DNA evidence, discussing how following such procedures is critical for its acceptance in courts. The purpose of Chapter-2 was to describe several landmark court cases that established standards for accepting complex technology and its results in court. Finally, the author provides a conclusion based on his research.

CHAPTER-1 : DNA FORENSICS

John Hyde

Over the last ten years, biological evidence has become increasingly prevalent in the courtroom, from when blood at a crime scene simply was used to show the brutality of a crime, to the blood being able to identify a suspect. With the growing importance of biological evidence in the courtroom, its improper handling or contamination can easily get this evidence thrown out. DNA forensics is the practice of proper collection, storage, and processing of DNA evidence that allows the evidence to be used in court. This technology is constantly improving, providing strong effects in the courtroom. This chapter covers current procedures for handling DNA at a crime scene, steps taken to prevent contamination of evidence, and some examples of where DNA forensics was a part of a court case.

Sources of DNA

Throughout the human body are a countless number of cells, and with the exception of red blood cells which lack a nucleus, each cell contains DNA. The amount of DNA found in different types of cells varies greatly depending on the cell type, making some body tissues or fluids preferable to others for use in DNA forensics. Blood is a good source, however the only DNA found in blood is in the white blood cells not the red blood cells (DNA Forensics, 1997). The best source of DNA comes from a sperm head, holding ten times as much DNA as found in the same volume of blood, which makes it the ideal biological evidence for use in a sexual assault case. Hair follicles from the base of a piece of human hair contain DNA, however the likelihood of finding unbroken hair follicles at a crime scene are unlikely. Saliva contains

epithelial cellular material that can be used as evidence, and in the case of the Unabomber was used as DNA evidence. Saliva can be salvaged from almost anything someone puts their mouth on, including cigarette butts, licked envelopes, toothpicks, pillows, and even bites. In cases where most of the tissue has decomposed, bones and teeth still contain enough DNA to identify who the remains belong to. Such techniques were used to identify the White Russian Romanov family long after their execution in the Bolshevik revolution (DNA Forensics, 1997). **Table-I** below shows a list of the types of evidence likely containing DNA, and its' likely location on the evidence. The list was developed by the National Commission of the Future of DNA Evidence (NCFDE) to teach law enforcement personnel the possible locations that DNA can be found at a crime scene.

Table-I: Types of Evidence Likely Containing DNA at a Crime Scene.

Evidence Type	Possible DNA Location	DNA Source
baseball bat or similar weapon	handle, end	sweat, skin, blood, tissue
hat, bandanna, or mask	inside	sweat, hair, dandruff
eyeglasses	nose or ear pieces, lens	sweat, skin
facial tissue, cotton swab	surface area	mucus, blood, sweat, semen, ear wax
dirty laundry	surface area	blood, sweat, semen
toothpick	tips	saliva
used cigarette	cigarette butt	saliva
stamp or envelope	licked area	saliva
tape or ligature	inside/outside surface	skin, sweat
bottle, can, or glass	sides, mouthpiece	saliva, sweat

used condom	inside/outside surface	vaginal or rectal cells
blanket, pillow, sheet	surface area	sweat, hair, semen, urine, saliva
"through and through" bullet	outside surface	blood, tissue
bite mark	person's skin or clothing	saliva
fingernail, partial fingernail	scrapings	blood, sweat, tissue

(Source DNA.gov 2003)

As seen in the Table, DNA can exist on almost anything a person touches, licks, sits on, or uses, which is the main reason DNA forensics has grown so quickly. The older a sample of DNA is, it may no longer have nucleated cellular material, but bones, hair, and teeth contain non-nucleated cells that may still have intact DNA. Alternatively, instead of analyzing nuclear DNA, mitochondrial DNA can sometimes be tested. Mitochondrial DNA is more abundant than nuclear DNA (each cell can contains hundreds or thousands of mitochondria), so mitochondrial DNA may be the only intact DNA present in old samples.

Evidence Collection

The growth of DNA as evidence in courtrooms depends on the ability of the sample to be authentically linked to the evidence without contamination or degradation. This technology is constantly improving, allowing more evidence to be used at trial, and spans everything from the original securing of the crime scene to help prevent contamination, to the collection of the DNA sample without contamination or degradation, to the purification of the DNA and its analysis.

Everything needs to be documented to help maintain a chain of custody to prevent evidence tampering.

Crime Scene Integrity

Starting from the crime scene, proper protocols must be followed to maintain the integrity of the crime scene to help prevent contamination of the evidence (Schwartz and Pilgrim, 2006). It is common practice for the first responding officer to secure the scene. But maintaining the integrity goes even further than that, as everyone who arrives at the scene subsequently cannot smoke, eat, drink, throw trash away, or liter. Doing any of these things would potentially contaminate the scene and allow good evidence to be thrown out of court.

Sample Documentation

Every sample must be documented as to the collection location, the date of collection, the sample number, the type of sample taken, the collector's initials, any comments on the condition of the sample (i.e. possible age, other environmental contaminants nearby, etc.) and if the sex is known. Properly recorded information will increase the evidence's usefulness in court.

The chain of custody is a complete record of every individual who interacts with that piece of evidence to provide a timeline for the evidence. Chain of custody can also be used to postulate how likely it is that the evidence collected was contaminated if that issue comes up later. Because even a tiny drop of saliva or a skin cell from another individual handling the evidence can cause contamination, the more people involved in the transport of the evidence the more likely contamination could occur (DNA.gov, 2003).

Evidence Storage

The last step before analyzing the DNA is storage of the evidence. DNA evidence must be properly stored to prevent contamination or degradation. If an officer stored a DNA sample long term in the trunk his police cruiser, the DNA could deteriorate. Ideally the DNA evidence should initially be put into a dry cold container, for instance a Styrofoam or similar waterproof container, in a cooler with ice. Then, once at the lab the DNA can be stored more effectively. Each type of biological sample needs a different type of treatment and storage. For example, for hair the proper storage depends on whether the sample is dry or wet. For a wet sample, a drying process could damage the hair, so it must be stored at room temperature, away from sunlight, submerged in a silica desiccant, or a silica gel used to keep moisture out of the sample (Schwartz and Pilgrim, 2006). If the hair found was dry, it can be placed in a dry envelope, out of sunlight, however this method is far less reliable and should not be used unless necessary. Urine, while not the best source of DNA, can also be stored. The best way to store urine is as a liquid with no additives, keeping it refrigerated and out of sunlight. For storage of organs or other solid tissue, there are three different ways. The most common is to submerge the sample in a silica desiccant and keep it at room temperature and out of sunlight. The next best method is to submerge the sample in 95% ethanol and keep it out of sunlight, in either a refrigerator or freezer. The final method is freezing, which allows the longest period of storing. The only issue with freezing samples is that when thawed, DNA degradation can occur, making freezing samples essentially a one-time solution (Schwartz and Pilgrim, 2006).

There are only a few ways of storing biological evidence long term. Freezing blood was found to be viable for a twenty year span that produced useable results. Storing purified DNA

can last longer, even decades, if properly done. Proper long-term storage of samples will allow unsolved cases to possibly be solved in the future.

Example Applications

The best used application of DNA fingerprinting is in paternity testing. In fact, the first case solved by DNA testing was a paternity case in England (Jeffreys et al., 1985) in which a son was allowed to immigrate to England after proving he was indeed the son of a British woman. The second, and far more visible application of DNA testing is solving violent crimes. This topic will be discussed in more detail in a later Chapter on DNA Databases. But , there are also other interesting uses of DNA forensics. One interesting use was after the world trade center attacks on September 11th, 2001. Proving who died in that tragedy was a challenge for forensics because the exact number and identity of the victims were unknown; most of the remains were only fragments of bone or body tissue. At the time of the attack there was no readily established system to identify victims in disasters with over five hundred victims. The National Institutes of Health and Justice developed a panel to develop kits for medical examiners to use for processing the DNA evidence found in the rubble (DNA 101, 2011). Over twenty thousand different pieces of human remains were recovered from ground zero. This led to a new data-sharing infrastructure between the state police department and the medical examiner's office to allow easy exchange of information. In 2005, the search was finally declared to be at an end, with only 1,585 of the 2,792 people known to have died in the tragedy being identified. The remainder of the human remains were too small to analyze (Sept 11 Panel, 2005). In 2007, the cases were reopened due to advances in STR/PCR technology, which needs a far smaller sample than the RFLP tests used during the early 2000's (DNA 101, 2011).

Another example of DNA testing is the DNA Shoah Project. This project uses DNA forensics to identify victims of the holocaust to help determine their lineage, with the hope of being able to reunite families separated in the holocaust and to aid in the identification of still unidentified remains (The DNA Shoah Project, 2003).

DNA forensics has also been used in human rights cases. During the early 1970s, Argentina was in the midst of a military dictatorship, and thousands of political activists were either murdered or simply vanished. Many of these activists were pregnant when they were abducted and were forced to give birth before they were murdered. Their children were illegally adopted by members of the military. Now a group called the Abuelas, the Grandmothers of the Plaza de Mayo in Buenos Aires, has gained the aid of a scientist named Mary-Claire King (University of Washington, 1996). With King's help, the grandparents of these "Disappeared" children are being rejoined with the families they lost. King tests the mitochondrial DNA of the children against the DNA of the grandmothers; since this type of DNA passes maternally it can be tracked from the grandmother to the grandchild. With enough time and support it is hoped that all of "the Disappeared" will be able to be returned to their true families (University of Washington, 1996).

Chapter-1 Conclusion

DNA forensics has come a long way since its creation in 1985. In the beginning, it was marred by poorly handled evidence, cross-contamination, and a large DNA sample size required for analysis. Now with an increase in the reliability and sensitivity of the technology, it has become a far more readily acceptable form of evidence in courtrooms, and is helping solve

mysteries around the world. It is hard to imagine where DNA forensics will be able to lead us next, and just how far the technology will be able to advance in the future.

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Chapter-2: Landmark DNA Court Cases

John Hyde

The introduction of DNA forensics into the courtroom has been a rather long and arduous process. DNA analysis is a complex technology, not easily understood by jurors, and in its early years the procedures were not well standardized leading to a lack of controlled analysis in some cases. The purpose of this chapter is to discuss several landmark DNA court cases showing how they altered the way DNA evidence is viewed and accepted in US courts.

US Courts and Burden of Proof

Before discussing landmark cases, the concept of "burden of proof" must be understood. Burden of proof means it is the responsibility of that party (prosecutor or defendant) to convince the judge or jury that their version of the facts is the truth. The burden of proof lies on different parties, depending on the type of trial. In a civil case (plaintiff versus defendant), the burden of proof lies on the shoulders of the plaintiff to make their case against the defendant, based on the "preponderance of the evidence". The punishment in a civil case is usually a payment or restitution to the injured party, but does not usually involve prison.

In a criminal trial (prosecutor versus defendant), the burden of proof lies on the prosecution to prove "beyond a reasonable doubt" that the defendant is guilty for the jury to give a guilty verdict. The stakes are higher in a criminal case, as a guilty verdict takes away the rights of the defendant and can include years of prison (Burden of Proof, 2011). Thus, DNA evidence can help convict the guilty or exonerate the innocent. But DNA typing is a relatively new technology, so in order for it to be allowed in courts legal precedents needed to be set.

Early US Cases and Technology

The first of the legal precedents for admitting complex technology in courts was set over one hundred years ago, a case that established the *Frye Standard* of admissibility (Calhoun, 2008). In 1923, Frye v US (1923), James Alonso Frye was found guilty of committing second degree murder. However, Frye continued to argue his innocence and appealed his case to Appeals Court of the District of Columbia. He took a then new "systolic blood pressure test" a precursor of the modern day polygraph test. Although he passed the test, and appeared to be telling the truth of his innocence, the court found that the systolic blood pressure test had not gained *general acceptance* in the scientific community, so the court did not allow the technique's results in court, and the original guilty verdict stood (The Frye Standard, 2011). Because we now know that suspects can fool a lie detector test by overriding their physiological responses, the results of this test remain inadmissible in most courts. The *Frye Standard* makes it necessary for any technology presented as evidence in court to have been tested extensively, and proven to be effective and reliable, which allows the jury to trust the testimony.

The problem with this system is the Frye Standard is difficult to actually achieve. To combat this in 1975 the *Federal Rules of Evidence* were created to help guide litigations in the courtroom. *Rule 702* of the Federal Rules of Evidence makes it possible for a witness, considered an expert due to specialized knowledge of the subject, to provide testimony on their own opinion of the matter (Rule 702, 2000; The Frye Standard, 2011). This ruling makes it possible for new technologies to be entered into testimony based on expert testimony. The problem with Rule 702 is that it allows any "expert" to provide testimony, even if the technology is unreliable. This can lead to juries believing false information, and possibly wrongly exonerating or convicting a defendant based on the expert testimonies.

The solution to this problem came with the case of *Daubert v. Merell Dow Pharmaceuticals, Inc.* (1993). In this case, the plaintiffs accused Merrell Dow of manufacturing a chemical that caused cancer. The plaintiffs lost their original trial, but eventually appealed the case to the US Supreme Court, as they wanted to provide an expert witness claiming to show the drug caused cancer. However, the Supreme Court ruled the expert witness would bias the jury, as the evidence was not that strong, so the court upheld the original not guilty verdict. Now, under what is now termed the *Daubert Standard*, any evidence based on new or unusual scientific knowledge is considered admissible if it satisfies four criteria: the technique has been tested, it has been peer reviewed, its error rates are known, and it is accepted in the scientific community (Dixon, 2001). The Supreme Court also ruled that it is up to the trial judges to throw out anything that would be considered as "Junk Science" (like the unproven cancer link in the original trial). This new standard has decreased the chance of junk science being allowed into the courtroom. With these standards in place, DNA forensics has had to prove itself extensively before being allowed in court.

Early British DNA Cases

Sarbah v. Home Office, or the Ghana Immigration Case

The first two cases that involved DNA forensics to solve them were both in the United Kingdom. The first was a non-violent paternity case called Sarbah vs. Home Office, or the Ghana Immigration Case. In 1983, thirteen year old Andrew Sarbah was held by the immigration department after his return from visiting his father in Ghana, and not allowed to return to his mother, Christiana. The immigration officials claimed that his passport was forged and would not allow him back into the country. Only after a Member of Parliament Martin

Stevens stepped in was Andrew allowed to stay temporarily in London with his family. Hammersmith Law Centre, a group that provides legal aid to the underprivileged (Genlex, 2011) compiled photographs and statements of family members. Tests for genetic markers clearly showed that Andrew was generally related to Christiana, however they could not prove that Christiana was Andrew's mother. The immigration office claimed that Christiana was just as likely to be Andrews's aunt as his mother.

The Law Centre found a new scientific technique claiming that it could prove maternity. The scientist who invented the process, Alec Jeffreys, took on the case and proceeded to take blood from Christiana, Andrew, an unrelated person, and all three of Christiana's other undisputed children. Jeffreys proceeded to make a DNA profile of each of the candidates and compared them to each other. The process showed that Andrew's fingerprint contained 25 bands that were directly inherited from Christiana (The First DNA Test, 2011). Jeffreys also reconstructed the fathers DNA from the bands of Andrew's siblings. Since the only bands were either from the father or from Christiana, there was approximately a one in a trillion chance that Christiana was not Andrew's mother. This conclusion brought the UK Home Office to use DNA evidence when available to solve future immigration cases. This landmark case proved that DNA can be used successfully to prove maternity, and has since been used extensively in immigration cases where lineage is not entirely clear (Genlex, 2011).

Colin Pitchfork

At almost the same time, in a town called Narborough in the United Kingdom, two 15 year old girls, Lynda Mann and Dawn Ashworth, where raped and murdered in 1983 and 1986, respectively. Semen was left at both crime scenes, and was collected to be used as evidence in

the case. The prime suspect at the time was a local schoolboy who lived in the same town as both girls. When questioned, he seemed to know information that had yet to be released about the Dawn Ashworth case, and eventually "confessed" to her rape and murder charges, but not for the first victim (Forensic Science, 2011). Local authorities believed that both crimes had been committed by the same man, and contacted Dr. Jeffreys to prove the link. Jeffreys had developed a way of creating DNA profiles not just for paternity cases but for forensic cases, and used the semen from both crimes (Genlex, 2011). He proved the semen from each crime scene came from the same man; however that profile did not match the boy who had confessed.

Officers then began screening men around the area using the DNA test. About 5,000 men were screened, but none of them were found to be a match. Only later when a local man bragged in a bar about how he had covered for a man called Colin Pitchfork in the screening did the police find their suspect. Pitchfork's blood was checked against the DNA profile from the crime scene, and was found to be a match. Pitchfork was sentenced to life in prison in 1988 (Forensic Science, 2011).

This case proved two very important things about DNA forensics. It was the first case where a DNA screening of a population was attempted, it was the first case in which DNA had been used to exonerate a suspect (the boy), and was the first case to use DNA to convict someone of murder. If the DNA profiling technique had not been invented, the local boy would most likely have been convicted of both murders, and Colin Pitchfork would have been able to continue killing innocent women. The Colin Pitchfork case proved just how effective and important DNA forensics can be when solving a violent crime.

Andrews v. State of Florida, 1988

The first case in the United States that involved DNA testing was the case of *Andrews v. State of Florida* (1988). Tommie Lee Andrews was accused of sexually assaulting a woman in her apartment on February 21, 1987. The victim said she was awakened when a man she described as a strong black male threatened her with a straight edge razor before raping her. The police knew Andrews from previous crimes, but could not link him to the crime scene. But semen was collected, and a DNA test was performed by LifeCodes Corporation to compare Andrews profile against the victim. The results showed that Andrews was the assailant, and he was convicted of the rape (*Andrews v State*, 1988). The importance of this trial is it was the first US case to convict someone based on DNA. The Frye Standard and Federal Rule 702 were used to allow expert testimony about the acceptance of the technique, its refereed literature, its error rates, etc. The prosecution used expert testimony to also show the tests were reliable, which allowed the evidence to be used (Genlex, 2011).

People v Castro, 1989

The unchallenged acceptance of DNA in US courts from Andrews 1988 lasted only one year. In 1987, Joseph Castro, a thirty eight year old Hispanic man, was charged with the murder of his 20 year old pregnant neighbor, Velma Ponce and her two year old daughter (*People v. Castro*, 1989). Both victims suffered from multiple stab wounds, which were found to be the cause of death. The main evidence in the case was a bloodstain found on the band of Castro's watch. In July 1987, Lifecodes Corp. analyzed the DNA in the stain, and concluded it was Mrs. Ponce's. Lifecodes claimed that the likelihood of the sample being someone else's blood was one in a hundred million. But before the case went to trial, Castro claimed he wanted the DNA

excluded from trial because the testing methods used by Lifecodes needed to be verified (The DNA Revolution, 2011).

In its consideration of the DNA evidence, the court decided to ignore past rulings that had allowed DNA evidence on the basis of the Downing relevancy test or the Rule 702 reliability test, and instead used only the Frye Standard of general acceptance. Throughout the pretrial, which was the most detailed analysis of DNA testing done at that time, thousands of pages of expert testimony was examined to make sure that the DNA tests were performed correctly. After weeks of analysis, Judge Gerald Sheindlin ruled on a three-pronged test to determine the admissibility of DNA evidence. The prongs are a combination of Frye's general acceptance standard, Rule 702 reliability standard, and a new standard about using accepted scientific techniques. The Three rules are as follows:

1. Is there a *generally accepted* theory in the scientific community which supports the conclusion that the tests can produce reliable results?
2. Are there techniques or experiments that currently exist that are capable of producing *reliable* results, and that are generally accepted in the scientific community?
3. Did the testing laboratory perform the *accepted scientific techniques* in analyzing the forensic samples in each specific case? (*People v. Castro,* 1989)

On August 14, 1989, the New York Supreme Court found that DNA forensic identification techniques satisfied prong-1 and prong-2, and they met the Frye Standard for general acceptance and the Rule 702 standard for reliability (The DNA Revolution, 2011). But for this particular case, prong-3 was not satisfied, it was found that Lifecodes did not perform accepted techniques with proper controls, and therefore the DNA evidence was not admissible. However, the Castro case never went to trial, Joseph Castro confessed to both murders (The DNA Revolution, 2011). The three prong Castro test was later modified by *US v Two Bulls* (1990) into a 5-prong test that is in use today, but the Castro provided a much needed serious

critique of the then new DNA testing technology, and eventually led to the formation of the Technical Working Group on DNA Methodology (TWGDAM), who helped standardize the technology.

It has been a difficult journey to allow complex DNA evidence in courtrooms. Since DNA analysis is a technology that is constantly adapting and becoming more accurate, its role in a courtroom likely will continue to change as well. One issue that has come up recently is a set of appeals claiming that the old DNA analysis techniques were inaccurate and so the conclusions based on them should be inadmissible. DNA evidence will continue to be scrutinized and the testing methods challenged as the technology continues to improve.

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PROJECT CONCLUSIONS

This project investigated the topic of DNA fingerprinting and its impact on humanity. The first chapter described the main methods for controlling a crime scene, for collecting DNA evidence, and for storing it, to help prevent contamination and degradation. The second chapter described several landmark court cases that set precedence for admitting complex evidence into court. This discussion ranged from the *Frye Standard* requiring the general scientific acceptance of new technology before it can be admitted, to more recent standards that require the tests be reliable, be properly performed with controls, and the evidence not be prejudicial. The author concludes that these forensic science advances and court case standards have strongly helped this complex technology gain widespread acceptance in courts today.