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DNA FINGERPRINTING

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ABSTRACT

DNA fingerprinting is a powerful new forensic technology, that many argue is the greatest tool in the history of forensic science. But as is often the case for new technologies, its acceptance by society was not straightforward. This project investigates this technology describing how it is done, its uses, and its indirect path of acceptance in the courtroom.

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PROJECT OBJECTIVE

The purpose of this IQP was to document the impact of a new technology on society. The topic chosen was DNA fingerprinting, that many argue is the greatest tool in the history of forensic science. It was chosen in part because of its powerful technology, well worth investigating, and in part because of its ongoing controversy in the courtroom, thus its impact on society could be documented.

CHAPTER-1: DNA FINGERPRINTING TYPES AND APPLICATIONS

DNA fingerprinting is one of the greatest identification systems we have to recognize an individual or living organism. Every living creature is genetically different in its own way, except for identical twins, triplets etc. DNA is comparable to a serial number for living things. Each individual contains a unique sequence that is specific to that one organism. Unlike traditional fingerprints which can be surgically altered or self mutilated, the DNA sequence can not easily be changed once the material is left at a crime scene, thus increasing its effective use in forensics, and the probability of finding an exact match. This method of identification is useful in many applications such as forensics, paternity testing, and molecular archeology, which we will discuss later on in this chapter. To further understand DNA fingerprinting we must first discuss the basics of DNA.

Introduction to DNA Basics

DNA, also known as deoxyribonucleic acid, contains a specific sequence of bases called nucleotides which contain the information of all the characteristics of living organisms. This information was inherited through the DNA of their parents. DNA is found in almost every cell of every living organism. The DNA represents the “instruction book” for making living organisms. The four nucleotides that constitute the sequences of DNA are adenine (A) which bonds exclusively with thymine (T), and

guanine (G) which bonds exclusively with cytosine (C). The molecular structure of DNA can be imagined as a zipper (Figure-1) with each tooth representing one of the four letters (A, C, G, or T) and with opposite teeth forming either of the two pairs, AT or GC (Betsch, 2005).

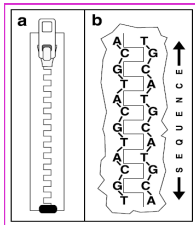


Figure 1. Schematic diagram of DNA structure. Part “a” shows a zipper which symbolizes the DNA structure. Part “b” shows a sequence of DNA in which one side bonds with the opposite side (Betsch, 2005).

A chromosome is the visible state of genetic material during the division phase of a cell. Humans have 23 pairs of chromosomes, which makes 46 individual chromosomes. Half of the chromosomes of an individual come from the mother and the other half from the father. Chromosomes are found in the nucleus, and contain a linear strand of DNA. The DNA molecule is twisted onto itself and the super-coiled molecule is enclosed in proteins which help maintain its shape. The chromosomes carry the genes that make each individual.

RFLPs and VNTRs

Now that we have a better understanding of what DNA actually is, let's move on to the basics of making a DNA fingerprint. There are three types of DNA fingerprints: RFLPs, VNTRs, and STRs.

Restriction fragment length polymorphisms, or RFLPs as they are commonly known, were the first type of DNA fingerprinting which came onto the scene in the mid-1980's. RFLP's focus on the size differences of certain genetic locations. The first step

in creating an RFLP fingerprint is obtaining and isolating the DNA. DNA can be obtained from almost any of the cells or tissues in the human body. You do not need a large amount of tissue or blood to provide enough DNA for analysis. The DNA is then extracted from the blood or tissue sample, and from here we carry out our second step in the process which is the cutting, sizing, and sorting of the DNA sample. DNA is cut using restriction enzymes, which cut the DNA strand at specific places. Restriction enzymes are usually isolated from bacteria that use them to degrade foreign DNA like viral DNA. Each type of restriction enzyme recognizes and cuts a particular DNA sequence.

The DNA at this point is cut into a various array of pieces which are sorted according by size through a process called electrophoresis. In this process the DNA particles are mixed into a buffer solution and applied to a gel made from seaweed agarose. Each side of the gel is connected to an electrical current. The DNA is negatively charged due to its phosphate groups, so it migrates towards the positive electrode or anode. The smaller pieces of DNA move faster (sieve) through the gel than the larger ones, so this provides the basis of the fragment separation. “This technique is the DNA equivalent of screening sand through a progressively finer mesh screens to determine particle sizes” (Betsch, 2005).

The band pattern that the DNA creates in the agarose gel is then transferred to a nylon sheet. To complete this transfer a nylon sheet is placed on the gel and left to soak overnight in a high salt solution. After the soaking procedure is completed, the nylon membrane contains the same pattern of DNA as occurred in the original gel. The membrane is now prepared to undergo its probing phase. Radioactive or fluorescently-

labeled probes are hybridized onto the nylon membrane, which bind to specific DNA sequences present in the pattern to produce a pattern of bands which create the DNA fingerprint. This process can be performed with several different probes simultaneously to make the final product which looks very similar to the bar codes you see in retail stores. Figure 2 shows an actual RFLP-type DNA fingerprint.

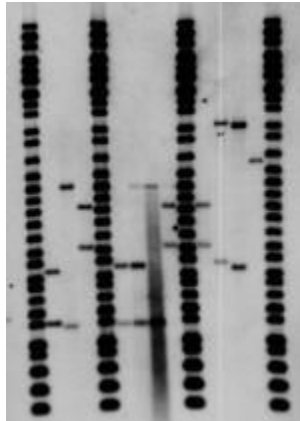


Figure 2. An example of a RFLP autoradiograph (RFLP Autorad Image, 2003).

Variable number tandem repeats, or VNTRs represent specific locations on a chromosome in which tandem repeats of 9-80 or more bases repeat a different number of times between individuals. These regions of DNA are readily analyzed using the RFLP approach and a probe specific to a VNTR locus. The fragments are a little shorter than RFLPs (about 1-2 kilo base pairs), but are created through the exact same process. Figure 3 shows an example of a VNTR fingerprint.

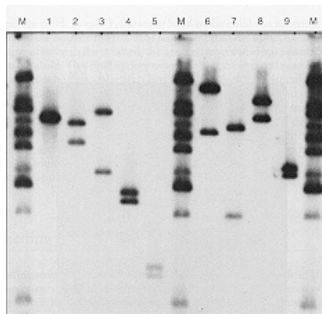


Figure 3. An example of a VNTR autoradiograph (Texas Tech, 2005).

Since RFLPs and VNTRs are created in the same fashion, they exhibit the same overall advantages and disadvantages. Some of the advantages of these types of DNA fingerprints are that they are the most stable and reproducible, which is a valuable trait to have when you are trying to determine an exact match of a person's DNA, which must exclude billions of other people's DNA with a certain degree of confidence. They are also easier to prevent contamination since the DNA sample is larger than with other types of DNA fingerprints, and small amounts of DNA contamination does not alter the analysis. Some of the disadvantages of RFLPs and VNTRs include they are very time consuming (especially the probe hybridization step), relatively large amounts of DNA must be used to obtain an adequate sample, too many polymorphisms may be present for a short probe, and the cost is very high due to labor and time requirements (RFLPs, 2004).

STRs and PCR

Currently, the most popular method of DNA fingerprinting are short tandem repeats, or STRs for short. Unlike VNTRs which analyze minisatellites that have repeat sequences of 9-80 base pairs, STRs use microsatellites which have repeat sequences of only 2-5 base pairs, introducing the "less is more" philosophy to the world of DNA fingerprinting. This was a big step forward in forensic science since the length of DNA fragment being analyzed is short enough to be amplified by polymerase chain reaction (PCR), so now we are able to analyze a very small sample of DNA that is quicker and easier than any previously known method and match it to a person's identity. PCR was developed in the mid 1980's and used the same principles that cells use to replicate DNA

to amplify the specified region, which is usually between 150-3,000 base pairs in length. In order to amplify the DNA sequence, a pair of short priming sequences (which are complimentary to the ends of the targeted sequence), a special heat-resistant DNA polymerase called Taq polymerase, and a solution of the four DNA bases are all mixed together in a test tube which contains a few copies of the targeted DNA sequence (Genetic Analysis, 2004). The DNA is then amplified (or replicated) by the repetition of a cycle which contains three vital steps:

- The solution is heated to 95°C to unzip the double helix DNA structure (Fig. 4A).
- The solution is cooled to 55°C to allow the primers to bind to the ends of the DNA (Fig-4B).
- The solution is then reheated to 75°C which is the optimal temperature for the Taq polymerase to create new copies of each DNA strand (Fig-5C).

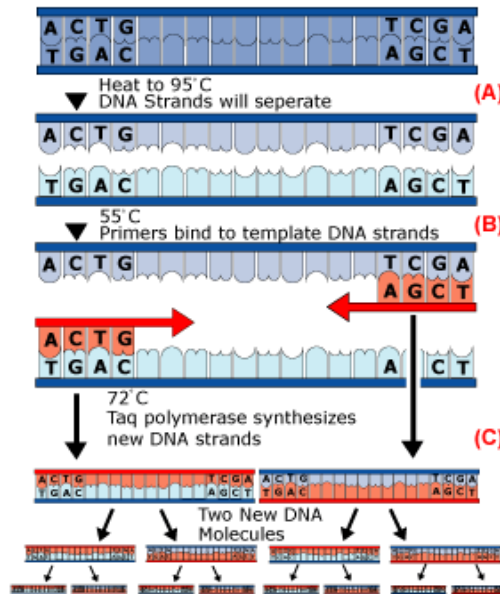


Figure 4. The three steps of the PCR cycle (Genetic Analysis, 2004).

One PCR cycle takes approximately 2 minutes to complete. Each cycle doubles the amount of the previous amount of targeted sequences in the test tube, so it only takes about 50 cycles to produce hundreds of thousands of DNA copies (Genetic Analysis,

2004). So long as primers are chosen to flank an STR site, the band amplified will represent the STR locus, and a simple gel or column will determine the band length. Thus this procedure avoids the lengthy probe hybridization step to membrane of the RFLP/VNTR approaches.

STRs are currently the most popular type of DNA fingerprint, since the whole PCR process takes only a few hours, compared to RFLP/VNTR probe hybridization and film exposure which can take several days. STRs can use much smaller samples of DNA than RFLPs/VNTRs, and can even use partially degraded DNA to create a fingerprint. Thus, the integrity and quality of the DNA sample is not as great a factor with STRs than with the traditional methods of DNA fingerprinting (Introduction to STRs, 2005). The current standard forensic protocol analyses 13 core STR loci which have been carefully chosen for their uniqueness. The only disadvantage of the STR approach is it is sensitive to contaminating DNA, so usually the STR approach is used first, followed by a VNTR analysis if contamination is suspected, and enough DNA is available.

Applications of DNA Fingerprinting

DNA fingerprinting is used in a variety of applications all over the world. They can be used to solve criminal cases such as rape, used to conduct a paternity test, or even used to determine the authenticity of rare sports memorabilia. Whatever the case, it is evident that DNA fingerprinting has revolutionized the way the world identifies biological matches. We will discuss a few examples of these applications and their importance below.

One of the first accepted uses of DNA fingerprinting was in the investigation of sexual assault and rape cases. Detectives only had to match the DNA of the semen found at the scene of the crime with the DNA of any potential suspect to determine who was guilty of committed the crime. A DNA sample from the rapist could be obtained from a simple vaginal swab from the victim or any other semen that was released in the area during the assault. The figure-6 below shows how a DNA fingerprint can help determine who is guilty of a sexual assault.

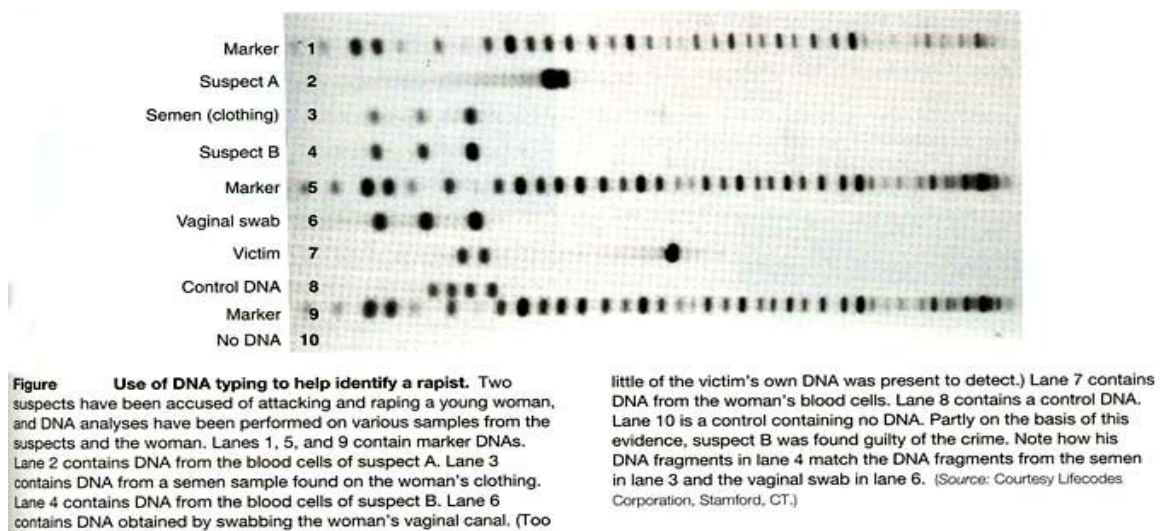


Figure 5. DNA fingerprinting used to solve a rape case (Miami, 2004).

As seen from figure-5, suspect B (lane 4) is guilty of rape because his DNA fragments match that of the semen found on the victim's clothes (lane 3) and also in the vagina (lane 6). Suspect A (lane 2) is clearly not the rapist because his DNA fragments do not match the semen found on the victim's clothes or the semen from the vaginal swab. DNA fingerprinting is very useful in such an application because it provides the police with an exact match of who left evidence at the crimescene.

Paternity tests are another application of DNA fingerprinting that has been incorporated around the world. In paternity tests potential fathers of the child have their DNA analyzed with the child and mother's DNA in order to see which of the potential fathers has the most DNA in common with the child in question. Figure 6 shows an example of a RFLP used to determine which potential father (F1 and F2) is the real father of the child (C). As you can see in the figure below, the second father tested (F2) seems to have more DNA in common with the child than that of the first father tested (F1).

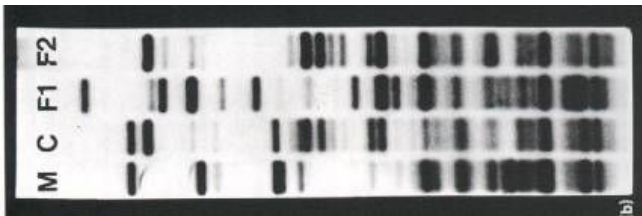


Figure 6. A paternity test using the RFLP technique (Paternity Test, 2005).

Another application of DNA fingerprinting is a more recent method in molecular archeology. This method of archeology uses DNA to determine a species of an archeological discovery or to trace blood lines of animal or human remains. DNA may be extracted from biological remains, hair, teeth, body tissues, or even fossils. The best climates to preserve DNA are very cold temperatures and arid climates. Some examples of specimens from these types of climates are the “Tyrolean Ice-Man”, who was found in the Alps, and the mummies of Egypt found in the dry desert. The ice man was found to be around 5300 years old, and DNA was extracted from the remains of his gut which found small traces of food that he ate (Ice Man, 2005). This was one of the most historic archeological discoveries in the last century. DNA fingerprinting is an important tool for archeologists to piece together information that links the past to us today. Figure 7 shows a picture of the “Tyrolean Ice-Man”.



Figure 7. The skeleton of a Neolithic man found in the Alps in 1991 (Ice Man, 2005).

DNA fingerprinting is even used in the world of sports collectibles. With sports collectors spending gigantic amounts of money to own a piece of sports history, there needed to be a way to validate the authenticity of the rare memorabilia. The memorabilia can be treated with a synthetic DNA smear, in which the item is coated with a secret DNA sequence where the original batch of DNA is then destroyed. The collectible can then be auctioned off giving the buyers assurance that the product is indeed authentic. This is just another instance of how DNA fingerprinting can be used in today's world.

CHAPTER-2: DNA FORENSICS

Forensic science is the art of piecing together a crime scene in order to determine how the crime was committed and who was responsible. DNA evidence is one of the most prominent pieces of evidence that is used in the United States judicial system today. Just because techniques exist that allow DNA to be analyzed at a crime scene does not necessarily mean that evidence was collected correctly to avoid contamination, or was stored correctly to prevent DNA degradation. As we will learn in Chapter-3 when we discuss landmark DNA court cases, many times DNA evidence has been prevented from use in a particular trial due to improper handling. The purpose of this chapter is to discuss some of the current knowledge about proper DNA handling.

DNA evidence can be collected by various means from almost any biological sample that was left at the scene of the crime. In the past when someone committed a crime such as a sexual assault, unless there were witnesses there was no real way of proving that a specific person was guilty. Normal blood types are not that exclusive. Now with DNA forensics, a level of certainty can be established that is recognized as valid evidence in a criminal case, either for the prosecution or the defense. There have been numerous instances where men were charged with rape in the past and had DNA analyzed from the crime scene only to find out that they were innocent all along. Figure 1 shows an example of how DNA analysis can help determine who is guilty of the crime in question. Note how the crime scene sample matches suspect 3. We will now discuss the proper techniques to conduct a forensic investigation.

Crime Scene
Suspect 1
Suspect 2
Suspect 3
Suspect 4



Figure 1. In the example shown on the left, DNA collected at the scene of a crime is compared with DNA samples collected from 4 possible suspects. The DNA has been cut into smaller pieces which are separated on a gel. The fragments from suspect 3 match those left at the scene of the crime, betraying the guilty party (Smith, 2004).

Forensic DNA and Collection Methods

DNA can be obtained from traces of biological fluids or tissues at a crime scene. The most traditional sources of forensic DNA come from saliva, seminal fluid, blood, and hair. DNA from saliva can be extracted from items such as cigarette butts, ski masks, envelopes, and stamps. Seminal fluids are usually found from oral, rectal, or vaginal swabs, and also on clothing. Blood stains and hair that are visible at a crime scene usually contain DNA that can be analyzed at the forensic laboratory (Kramer, 2002).

Collecting the DNA during a forensic investigation may be the most crucial step in terms of the analysis results. The first step in collecting evidence is searching for it. When examining a crime scene for evidence, a plan should be devised to insure complete coverage of the area. For indoor crime scenes, the area will be searched room-by-room, with each room divided into sectors. This examination technique is called the zone method. For outdoor areas, searches are conducted by covering the area in parallel rows, until the whole crime scene has been investigated. This technique is called the grid method.

When collecting DNA from a crime scene it is ideal to obtain the original item that contains the evidence. For example, if you were investigating a sexual assault it would be ideal to collect undergarments worn after the incident rather than swabbing the

original evidence (Kramer, 2002). This is not always possible to do when the original item containing the DNA evidence is too large to collect, such as a sofa, but patches of covering can be collected. For floors, individual tiles can be collected. In order to successfully swab the DNA you must use a cotton tipped swab and slightly moisten the tip with clean water. Then once the stain is absorbed by the swab let it air dry. Do not dry the sample by any other means because the heat could denature or contaminate the DNA sample. After the sample is dried package the cotton swab separately in paper and keep the sample out of direct sunlight (Kramer, 2002).

Another method used for collection of DNA material at a crime scene is a tape lift. This is primarily used for dried blood samples which are fixed to non-porous surfaces. Traditional fingerprint tape can be used to do this, which is then placed sticky side down onto a piece of white paper. The tape lift should then be sealed in a separate envelope to prevent any contamination.

When collecting DNA evidence at a crime scene investigation, the forensic scientist should also collect control samples to assure that the sample is pure. Control samples are specimens of any foreign substance or material that may have contaminated the DNA. The control samples can then be analyzed separately from the other evidence to determine if any contamination exists.

When examining a crime scene for DNA one must remember to wear protective gloves and any other necessary protection in order to prevent contamination of the sample, and also to protect you from any possible diseases. Other kinds of collection methods for evidence include obtaining the original items at the scene that the actual sample is on.

Ways to Prevent Contamination

Contamination is one of the greatest risks that the evidence must be guarded from. If your sample of evidence is found to be contaminated, it can be thrown out as evidence in the courtroom. Contamination can occur at the crime scene, during packaging, in transit to the laboratory, and also during analysis. With a risk of possible contamination present in all these steps of the forensic process, proper precautions must be used to prevent ruining the DNA sample.

At the crime scene many factors must be considered in trying to prevent contamination. The first factor is Mother Nature. The outdoor elements can play key roles in ruining evidence at the crime scene. For example, if it rained at the crime scene, a blood stain found could be diluted which would be almost impossible to analyze. Also if it was windy that day then vital pieces of DNA could have been blown away from the crime scene (Baldwin, 2005). Another factor at the crime scene is properly securing the area so that people do not taint the evidence. Until a crime scene is secured many individuals not related to the event may have left DNA around key evidence which may be mistaken for a possible suspect. Equipment is another factor which must be regulated to reduce the risk of evidence contamination. Clothing, notepads, photography equipment, and crime scene kits must be properly decontaminated once leaving a crime scene or they may contaminate evidence at another crime scene. Disposable personal protective equipment (PPE) should be worn including: a mask, jumpsuit, gloves, booties and head cover (Baldwin, 2005). By keeping these tips in mind, contamination at a crime scene should be at a minimum.

During packaging and transport of the DNA evidence, there are also a few factors to keep in mind in order to preserve the sample in its original state. When packaging evidence, each sample should be sealed individually to prevent cross-contamination. Biological fluids should be dried in order to avoid contamination by bacteria (Baldwin, 2005). Evidence should be packaged in a paper container, which is then put into an open plastic container to reduce the risk of evidence leaking out while in transit. When the biological sample is in transit certain precautions must be taken. DNA is sensitive to temperature which means that while the sample is in transit, the package must be out of direct sunlight or any other extreme circumstance. Proper arrangements must be coordinated before transportation so that the evidence can be properly stored until it is ready to be analyzed.

During analysis of the DNA evidence in the laboratory, a few things must be considered that will aid in achieving optimal analysis. When the sample of evidence is in temporary storage, it should be examined to determine if any other samples around it might have leaked on to the sample. Proper procedures should be followed as stated by the laboratory's guidelines.

Storage Methods of DNA

Biological materials are very sensitive to the conditions around them, so storage of DNA is an important part of maintaining useful evidence. The samples acquired from the crime scene should be kept away from high temperatures. Room temperature is acceptable, refrigeration is desirable, and freezing is preferred when

it comes to storing a sample. Figure 2 shows a DNA freezer that is used to store samples.



Figure 2. DNA freezer used to store samples (Gorgeous Genome, 2004).

If the samples are not stored to proper specifications the DNA will deteriorate and will not be able to provide proper analysis. Freezers that are “frost-free” are the most ideal when it comes to storage equipment.

DNA at an Aged Crime Scene

At an aged crime scene, forensic scientists attempt to retrieve DNA evidence that is the least contaminated and decomposed. For example, if a deceased individual is at an aged crime scene and is showing signs of decomposition, then blood work would not be a practical route of obtaining a valid DNA sample (Kramer, 2002). If hair is present on the deceased body, the sample must be pulled from the tissue because the tissue attached to the hair root is necessary for DNA analysis. Bones and teeth would also serve as a suitable sample of DNA evidence, since they take very long to degrade. Another method to collect useful evidence at an aged crime scene would be to look for property that was associated with the individual’s body such as a hairbrush or toothbrush. Figure 3 shows a body at an aged crime scene showing some obvious decomposition.



Figure 3. A deceased individual at an aged crime scene showing obvious stages of decomposition (Dead Body, 1997).

Advances in Forensics

Over the past ten years there have been many advances in DNA collection techniques that allow this type of evidence in the courtroom today. Standards have been set on all aspects of crime scene investigations, that help create consistency with all evidence. DNA is now allowed in the courtroom due to the techniques discussed in the chapter to properly collect, transport, analyze, and store the DNA sample without contamination or degradation. When a sample of DNA is kept in its original state it proves to be one of the most reliable pieces of evidence in the courtroom. Now we will discuss technological advancements in the world of forensics.

When examining a crime scene it may seem that the lawbreaker got away without a trace. In the past, violent crimes have been committed and cleaned up leaving no visible proof of the crime. We now know that tiny particles of biological fluids, most notably blood, can cling to most surfaces at the crime scene for many years without anyone ever realizing they are there (Harris, 2005). There is now a chemical that allows you to see these microscopic particles of blood and find the clues, that to the naked eye, did not seem to exist. The chemical is called luminol and it reveals these particles with a light-producing chemical reaction between hemoglobin and several chemicals (Harris, 2005). Light is produced because the reactants contain more energy than the products of

the reaction, which release the extra energy in the form of light photons. This is the same process that makes fireflies glow, which is called chemiluminescence. After the chemical is sprayed onto the object in question, a blue glow will emit in any areas where there are tiny traces of blood, an example of which is shown in figure 4.



Figure 4. A simulation of luminol at work. The chemical binds to the blood and emits a blue glow (Harris, 2005).

This technique is used typically at violent crime scenes, where the suspect could have murdered the victim and got rid of all visible evidence from the area. Once the luminol reacts with the small traces of blood left behind, forensic investigators will takes pictures or videotape the crime scene to record any potential patterns (Harris, 2005). It should be noted that once blood reacts with luminol, that sample is no longer able to provide DNA for analysis. Perhaps in the future a new method of visualization will be devised that maintains DNA structure.

CHAPTER-3: LANDMARK DNA COURT CASES

Having discussed the technology of DNA fingerprints and forensics, we can now focus our attention on the impact of this new technology on society. Although the technology has been described as the greatest forensic tool in the history of forensic science, the acceptance of any new technology in US courts is not necessarily straightforward. This chapter describes some landmark cases that helped establish legal precedence for accepting DNA fingerprinting evidence in courts, including some early cases that pertained to technical evidence but did not involve DNA.

Frye v. United States (1923)

In a District Court, James Alphonzo Frye was originally convicted of second-degree murder in 1923, but the case was appealed to the Supreme Court of the District of Columbia based on the premise that Frye had previously passed a “lie detector test” proving his innocence. Such tests were new at that time, so the supreme court questioned whether this new technology had any published scientific studies to back it up, and whether it was *generally accepted* in the scientific community, eventually ruling the lie detector technology was not generally accepted. Thus the earlier District Court had properly excluded this evidence, and the original guilty verdict stood (Frye v. United States, 1923). Although Frye was released from prison after only 3 years because another person confessed to the crime, the Frye Standard of *general acceptance* was used for several decades as the gold standard for allowing technical evidence in courts (Bernstein, 2001). Unfortunately the Frye standard is difficult to achieve in real life,

especially for new technologies, so courts sometimes resorted to the more lenient “Rule 702” (see below). DNA evidence did not achieve the rigorous Frye Standard until the case of *U.S. v Two Bulls*, 1990.

Federal Rule of Evidence 702 (1975)

In 1975, the US Congress adopted the “Federal Rules of Evidence 702” (Federal Rules of Evidence Online, 2003; Moenssens, 2004) because the Frye Standard for general acceptance was difficult to achieve in the courtroom. “Rule 702” was more lenient and flexible than the Frye Standard, stressing *helpfulness, reliability, and relevance* of the technique rather than general acceptance.

U.S. v. Downing (1985)

In 1985 in the U.S. District Court for the Eastern District of Pennsylvania, John W. Downing was charged with mail fraud, wire fraud, and the interstate transportation of stolen property (*U.S. v. Downing*, 1985). Downing led a group called the “Universal League of Clergy” who defrauded vendors by collecting money from them, but did not deliver the goods. The prosecution’s case included 12 eyewitness testimonies claiming Downing was the man they knew as Reverend Claymore who had defrauded them. The defense argued that eyewitness testimony was generally unreliable, and wished to use a psychologist as expert to prove that point, but the District Court denied the defense request, ruling the psychologist’s testimony did not meet the *helpfulness standard* of Rule 702, and found him guilty of all counts (except the interstate transportation of stolen property).

In a bizzre twist to the case, Downing appealed the District Court decision on the basis that “eyewitness testimony is accurate”, although those witnesses help convict him, it would get him a retrial. In the appeal, the U.S. Court of Appeals for the Third Circuit held that the District Court was wrong in its decision to exclude the psychologist’s expert testimony, and remanded the case back to the District Court with instructions to conduct an evidentiary hearing on the admissibility of expert testimony. The hearing failed to reinstate the expert witness, so the original guilty verdict stood (U.S. v Downing, 1985). This case helped establish the role of a *relevancy hearing* to determine the usefulness of expert technical witnesses, which outweighs the Frye Standard (Harvard Law Publications, 1999).

Andrews v. State of Florida, 1988

Tommie Lee Andrews was a suspect in more than twenty assaults in the Orlando area in 1986, but he was finally linked to a rape in 1987 when Lifecodes (Valhalla, NY) matched his DNA to semen left at the crimescene (Andrews v. State, 1988). Because DNA testing had not yet been used in a U.S. criminal case, a relevancy hearing was performed which concluded DNA testing is “scientifically reliable in method, theory, and interpretation, and positively reviewed by peers” (Andrews v. State, 1988). The DNA evidence was allowed, but not the impressive statistical evidence that the prosecution could not validate.

Although the first trial ended in a hung jury, at the retrial the DNA evidence was again admitted, along with the statistical data (allowed by applying the *Downing relevancy test* and the *Rule 702 reliability test*), and Andrew’s regular fingerprints left on

a windowsill, and his identification by the most recent victim in a photo-lineup. It took the jury only a short time to convict him, and he became the first person in the U.S. convicted of a crime based on DNA evidence. Andrews appealed the verdict, but on November 22, 1988, the original convictions and sentences were affirmed (*Andrews v. State*, 1988).

Soon after that trial, Andrews DNA was found to match that of other several other victims in the Orlando area, and his prison sentence went from an initial twenty-two years for rape, to over a one hundred years for serial rape. “Following *Andrews v. State*, DNA testing can now more easily be applied to future cases involving sexual assault and other crimes of violence (Coleman and Swenson, 2003).

People v. Castro (1989)

This case represents the most critical assessment of DNA technology at the time (Coleman and Swenson, 2003). Joseph Castro, a thirty-eight year old Hispanic, was accused of murdering his pregnant neighbor, twenty-year old Vilma Ponce, and her two-year old daughter (*People v. Castro*, 1989). Lifecodes Corp. analyzed a bloodstain on Castro’s watch and found it to match to the victims, with the chance of a random match in the hispanic population being one in one hundred million.

Ignoring the 1988 Andrews ruling based on the Downing *relevancy* test, and the Rule 702 *reliability* test, the New York Supreme Court investigated the admissibility of DNA tests in a pretrial hearing applying the rigorous *Frye standard*. Following thousands of pages of expert testimony over 12 weeks, in August 1989, Judge Gerald Sheindlin developed a three-pronged test to determine whether DNA evidence should be

admitted: 1. Is there a generally accepted theory in the scientific community which supports the conclusion that DNA forensic testing can produce reliable results? 2. 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? 3. Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case? (People v. Castro, 1989).

On August 14, 1989, the New York Supreme Court held that Castro prong-1 and prong-2 met the Frye Standard, but not prong-3 in this particular case (People v. Castro, 1989) since Lifecodes did not use generally accepted scientific techniques for obtaining their results. Although the DNA evidence was ruled inadmissible, the case never went to trial, Castro confessed to the murders in late 1989.

The Castro *three prong test* served as a standard for which other DNA evidence cases were judged, highlighting the need for rigorous experimental standards for performing DNA fingerprinting. Following the rigorous hearing, the FBI created its “Technical Working Group on DNA Analysis Methods” or TWGDAM, whose universal recommendations remain in effect to this date (Federal Bureau ...1998).

People v. Miles (1991)

The State of Illinois convicted Reggie Miles in 1991 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 (People v. Miles, 1991). The evidence included regular

fingerprints and DNA that matched the defendant, performed by Cellmark Diagnostics (Maryland) following the then newly established FBI TWIGDAM guidelines.

Miles appealed the convictions in the Appellate Court of Illinois, Fourth District, arguing Cellmark did not use procedures that give reliable results, but the appellate court denied his appeal, upholding the earlier conviction. This case provided overall strong support for DNA evidence, verified the TWGDAM guidelines, and made subsequent DNA cases easier to prove.

CONCLUSIONS

DNA fingerprinting is the most sophisticated way to identify living organisms. DNA is a unique piece of genetic material within biological organisms, which have characteristics that are one of a kind. DNA cannot easily be altered once it is left at a crime scene or deposited with a mummy, which makes it a strong forensic tool. RFLPs and VNTRs are the traditional methods of fingerprinting DNA, which uses a relatively large sample that uses the method of probe hybridization to detect polymorphisms in the DNA. STRs are the most current form of DNA fingerprinting, which is PCR based and uses a very small sample of DNA. DNA fingerprinting has many applications that range from criminal rape cases, paternity tests, molecular archeology, sports memorabilia, etc. The DNA molecule is like a snowflake in that there are no two exactly alike, but is one of the only things in common that all biological organisms are created with.

DNA forensics is one of the greatest tools in piecing together a crime scene. Over the past ten years there have been many advances in the methods of collecting and preserving these DNA samples to help facilitate the acceptance of this evidence in the court room. By avoiding contamination and properly storing it to prevent degradation, forensic science has made a monumental step in allowing DNA samples as valid evidence in United States courtrooms. DNA evidence is now one of the most powerful tools used in determining who is responsible for a crime. With criminals altering their fingerprints and other physical characteristics, DNA evidence is one of the only true methods to correctly identify an individual. Now with the help of chemicals such as

luminol, crime scenes that at first analysis seem to have no physical evidence are further examined on the particle level which makes it almost impossible to leave a crime without a trace. Although there are still some factors that make it difficult to preserve a good DNA sample, progress will continue to be made in the field of forensic science, which seems to have a limitless future in technology to come.

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