Senior Thesis

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DNA and Fingerprints: Useful Forensic Tools or Challenges to the Justice System?

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(Natural Sciences)

2012
Introduction

The field of forensic science has improved criminal investigation in ways that could not have been imagined fifty years ago. With advancements in science and technology, newer and more effective techniques for the identification of criminals are available to police and criminal investigators. Since the earliest methods for the identification of individuals became available, there have been attempts to improve and redefine these techniques to keep up with modern advancements. Over the past hundred years, there have been some of the most important and significant advancements to the field. Technological advancements from the dawn of the age of the computer to the beginning of the age of the internet, have all created easier and more efficient ways of criminal investigation. Police departments throughout the United States and in other countries now have ways to easily store and share information and eliminate problems that traditional paper records posed. The advent of the internet, allows instant communication and sharing of information that is often vital in the fast paced world of criminal investigation.

Scientific advancements from the discovery of DNA to more precise methods of trace evidence analysis have also led to unfathomable changes in the field of forensic science. The discovery of DNA paved the way for more statistically significant identification of a suspect or victim than the fingerprint had been previously able to do. This discovery also allowed for identification of victims in the cases of mass casualty situations such as the terrorist attacks of September 11, 2001.

This does not mean that these advancements have come into use without resistance and controversy. There are many that feel that as technology improves, and thereby criminal investigation improves, people’s basic rights and liberties are being infringed upon. The advent of DNA identification created uproar throughout the scientific community about practical
criminal uses of this technology. Courts faced these issues for many years and though the technology is currently accepted in courts throughout the world, there are still those that feel that the field of DNA identification needs more research to be properly understood and widely used. Along this same line of reasoning, there are advocates out there that feel fingerprint identification should be the standard identification evidence used in courts throughout the world because of the long standing research available. There seems to be no good answer to either side of this debate, particularly as the technologies continue to advance and people become more involved on both sides of the debate.

The scope of this paper is meant to investigate both sides of the fingerprint versus DNA identification debate. Through background information on each method, as well as arguments from opponents and proponents, a thorough understanding of the technology will be presented. As well as this, there will be an analysis of the emerging databases for both DNA and fingerprints that are more often playing into criminal investigations and whether or not these databases are advancing the field. Databases have come under great fire because of the unknown lines of who should and should not be entered and how this information should be used outside of the field of criminal investigation.

Following from this, case study analyses of famous cases involving each method will be presented. These case study analyses will present both the advantages and disadvantages of criminal application of DNA and fingerprint identification. The Night Stalker case will be analyzed as a prime example of how just one fingerprint can solve a case. If it had not been for the single mistake that Richard Ramirez made during his first crime, the killings and assaults of at least fourteen people may never have been solved. This case is an example of how important fingerprint databases are in order to help solve criminal cases. The trial of OJ Simpson will be
used as case study for DNA identification. This case shows the importance for proper evidence collection and how this can lead to the acquittal of a seemingly guilty man. This case centered on whether or not the DNA evidence, central to the possible conviction, was properly collected and analyzed. These are just two of several cases that will be used to demonstrate how fingerprint and DNA evidence can be used to incriminate or exonerate a suspect in a crime.

In the end there will be a brief discussion of the so-called “CSI effect” that plagues investigators and criminal trials as shows such as CSI become more popular in current culture. There is rising support for definitive forensic evidence that is often not as clear cut as is shown on television and leads to greater acquittal rates when evidence is not present. The Amanda Knox case is a perfect example of how this has become a problem in our society. The case that will be used as an example of this effect, however, is the Casey Anthony trial. The entire case centered on new and emerging forensic techniques that were meant to tie Casey Anthony to the murder of her daughter, Caylee. In a day and age when jurors look the hard proof that a suspect was the perpetrator of a crime, investigators look to find this evidence even if the science to back it up was not present.

In order to fully appreciate and understand how DNA and fingerprint identification developed and became what they are today in the world of forensic science, it is important to understand how the field evolved. In the section that is to follow, a comprehensive overview of how the field came to be, including some of the more important discoveries, will be explored. This will not include the discoveries related to fingerprint and DNA identification because these topics will be discussed in greater detail later on.
History and Development of Modern Forensic Science

Forensic science can be understood as the broad application of many fields of science to answer questions raised through investigations of crime. This broad definition encompasses many areas of science from pathology to entomology as well as psychology and psychiatry. All of these areas come together to help police and attorneys answer legal questions associated with crime. The term forensic comes from the Latin forēnsis, which means “of or before the forum”.

This term came about because in ancient Roman times, criminal charges were brought before a panel of officials in the forum. It was this panel that would determine whether or not a person was guilty of the crime they were being charged with and what the punishment for that crime would be. This is similar to the way that our current legal system works and thus the term has remained over the years.

Forensic science has been around in some form or another since some of the earliest police forces. The field can be traced back as early as the Middle Ages when Archimedes was asked to determine if the king’s crown contained any silver or if it was pure gold. Evidence exists that there may have been even earlier applications of the uniqueness of fingerprints.

Throughout the years there were many discoveries that began to shape many aspects of the field of forensic science. These discoveries included methods for the differentiation of hair samples under the microscope as well as some of the first discoveries relating to the field of toxicology.

During this time, there were many discoveries that led to some of the earliest methods for determining components of blood that could be used to identify the presence of blood. As the industrial revolution brought better technology there were more and more advancements that were possible.
It was not until the 1830s that unique characteristics of the human body were documented to be used to differentiate one person from another. One of the most significant discoveries was made by Adolphe Quetelet, who when stating his belief that no two human bodies were completely alike set the foundation for Bertillon’s work years later. Not until the 1880s did Alphonse Bertillon develop the study of anthropometry. The method he developed took a series of measurements of different parts of the body to compile a set of measurements that was proposed to be different from one person to another. These measurements were taken of the bony structure of the human body, including the distance between eye sockets and the length of arm and leg bones, which change only minimally once a person reaches adulthood. All of these measurements were taken and recorded on cards that were filed and stored at prisons and police stations all over. These measurements and cards were aimed at targeting and apprehending repeat offenders.

By the end of the 19th century, books had been published that explored the uses and applications of both physical evidence and fingerprints in criminal investigation. Hans Gross in 1891 wrote the book *Criminal Investigation* which explored the use of physical evidence. It was the first book of its type that included a comprehensive look at the uses of physical evidence for the purposes of solving crime. Gross is also commonly credited with being the first person to coin the term “criminalistics”. His book helped to define and establish the science of forensics and was the first of its kind paving the way for others. The terms and ideas described and discussed in the book helped shape the methods and practices of evidence collection and the developments to the field of forensics that came after its publication.

The beginning of the 20th century brought with it more precise methods for the identification of individuals. Greater understandings of the human body and other aspects of
biology led the way for improved identification and classifications of blood samples. Karl Landsteiner was the first person to determine that blood was not the same from one person to another\(^2\). He determined there were several different blood groups that existed within the population. Further research from Max Richter, developed a method for typing blood stains to determine which group a sample belonged to\(^1\). This was the first method of its type developed to help further techniques for forensic application. By 1915, there was the first antibody test developed for the typing of ABO blood groups\(^2\).

Throughout the late 19\(^{th}\) and early 20\(^{th}\) centuries, as the use of guns increased, more techniques were developed to study the characteristics of guns and bullets for forensic application. It was during this time that the individualizing markings on each spent bullet were found to be different depending on the gun from which the bullet was fired\(^1\). By the late 1920s the comparison microscope was frequently used to compare bullets to each other to help in the identification of the weapon used in a crime. Throughout this period, gun makers began to compile databases of the unique markings that each gun left on a bullet, a study that became known as ballistics\(^1\). In addition to this, ballistics comparisons were being used to help determine if a gun had fired a bullet that was found at a crime scene. A further discovery during this time found that these unique markings were not found only on bullets, but also on spent cartridge casings and shell casings, both of which are left after a bullet has been fired\(^1\). In 1991, the Integrated Ballistics Identification System (IBIS) was developed in Canada to have a centralized location for comparison of markings left on all bullets, shell casings and cartridge casings. In the same year there was collaboration with the Bureau of Alcohol, Tobacco and Firearms to bring the system to the United States\(^1\). This is just one example, other than DNA and
fingerprints, in which developments in technology and computers significantly impacted and advanced forensic identification.

**History of Fingerprint Identification**

There is evidence that even before the time of Archimedes, people in China and other parts of Asia used fingerprints to sign contracts and identify documents and sculptures. The field made little advancement from this point until 1686 when Marcello Malpighi was the first to note the differing characteristics of fingerprints. At the time, he made no indication of their usefulness in identification of individuals and thus the possibilities were not explored until much later. Not until the early 1800s the first paper was published by John Evangelist Purkinji suggesting a classification system for fingerprints using nine categories. Again there was no mention of the individualizing properties of fingerprints and their ability to distinguish one person from another.

In 1892, *Fingerprints* was published by Sir Francis Galton. This book contained the first extensive description of the nature of fingerprints and how they could be used in criminal investigations. Four years later, Sir Edward Richard Henry published *Classification and Uses of Finger Prints*. The classification system for fingerprints was established that would be used for many years in Europe and North America. The beginning of the 20th century brought with it the first uses of fingerprints in criminal investigation in England and the United States, in place of the Bertillon system of identification. In 1903, fingerprint identification gained immense support after the Bertillon method failed to differentiate two inmates from one another. The case of mistaken identity of Will West at Leavenworth Federal Penitentiary showed that two
individuals could have nearly identical Bertillon measurements but still have significantly different fingerprints\textsuperscript{1}.

By 1920, there were suggestions as to how many points of comparison were necessary to classify that two fingerprints were identical. Edmond Locard was the first to suggest that twelve points was sufficient to classify a positive match\textsuperscript{1}. By 1977, the Federal Bureau of Investigation had begun its Automated Fingerprint Identification System (AFIS). This was a program that contained the computerized fingerprints of suspects and those found at crime scenes in order for comparison and identification purposes\textsuperscript{3}. In 1999, the FBI upgraded their fingerprint database making it fully computerized and thus implementing the Integrated Automated Fingerprint Identification System (IAFIS)\textsuperscript{3}. This new system made for completely paperless submission of fingerprints, as well as paperless storage and search capabilities. Police departments throughout the nation could now share fingerprints collected from crime scenes, suspects, and victims. The implementation of this new system allowed for faster communication between areas and provided the possibility to link crimes on opposite ends of the country in a matter of minutes. IAFIS also paved the way for identification of unknown victims if for any reason they were previously in the system\textsuperscript{3}.

Along with fingerprints and the corresponding person’s name, IAFIS contains a wealth of other information that can be useful. Corresponding mug shots, physical information including hair and eye color, height and weight as well as tattoos, scars and other unique marking, are contained in the records of a single fingerprint or fingerprint set\textsuperscript{4}. There are many ways a person can end up in the database currently. Among the most commonly entered prints are those of suspects and other persons convicted of crimes, along with all current and past serving military personal and government employees. There are many other civil employees whose fingerprints
end up in the database for a variety of reasons. Fingerprint and criminal histories of individuals are currently submitted to the database voluntarily by local, state, and federal police agencies. The database currently is home to more than 70 million files in the criminal master file along with more than 31 million civil records. In 2010, the database processed more than 61 million submissions. With all of these records, a typical comprehensive search takes about 27 minutes and a civil search takes about an hour and twelve minutes. Searches for similar prints can now take as little as ten minutes, a process that once took weeks.

The use of fingerprints has now expanded far beyond the identification of a corpse and the matching of an unknown print at a crime scene to a suspect. Private companies, along with most federal and state governmental agencies, use fingerprints in a number of capacities. Most commonly, they are used to help assist in the hiring of individuals and determining if a candidate is well suited for a position within a company. As part of the application and interview process, an increasing number of companies are asking applicants to be fingerprinted as part of a comprehensive background check before hiring. Fingerprints are then sent to an AFIS database, typically the FBI, to be compared to all other prints in the system. This allows a company to know if an applicant has been fingerprinted and entered into the system for any reason, including military service and arrest in connection to a crime. These background checks can often be a deciding factor in whether or not an applicant gets hired. This practice was once only common to governmental hiring, including within the military, police, and other security related positions. As our world changes and the threat of terrorism and other crime increases, private companies have begun to implement this practice. There is heated debate over this practice centering on whether or not it is an invasion of privacy. Skeptics of fingerprinting job applicants also raise the concern of these prints being added to the databases and being used in
criminal investigation. Both of these are concerns in today’s society but will be discussed later 
on when focus is turned to the problems and concerns of fingerprint use in criminal investigation.

Fingerprint databases now exist in almost every state as well as the FBI. These systems 
are generally known as Automated Fingerprint Identification Systems, or AFIS. Within each 
state, it is common practice that most jurisdictions have access to all other jurisdictions’ 
databases. This is not always the case, particularly when there are several versions of software 
being used in one state. Each company that produces fingerprint database software does not 
always make their software compatible with one another. The need continues to exist, in many 
instances, for fingerprints to be sent to several places before a comprehensive search of all 
fingerprints can be completed. This is typically found to be an issue between the state and 
federal databases. Most states have a general practice of sending unknown fingerprints to the 
FBI periodically; helping to keep the nation unified as a whole and creating a greater central 
database. Once the software for AFIS databases overcomes the differences, identifications will 
become more accessible and faster for all jurisdictions.

This is not to say that the world of fingerprint identification has completely moved away 
from matches made by trained technicians. There are still many instances when manual 
identifications can be less time consuming and preferred over AFIS methods. Identifications 
made in this manner are common when a relative or other person believes that the identity of a 
victim is known. Reference prints are then taken from the person’s home or workplace and 
used as a marker for comparison. Technician identification can also be used as preliminary 
method of identification of suspects or victims, or to determine if two prints are from the same 
person. Once a preliminary match is made, it is often supported with an AFIS identification to 
be used in court or other legal documents and reports. The main issue with manual
identifications, that have brought the field towards AFIS identifications, is that a greater level of uncertainty and possibility for mistake exists\(^4\). Computer systems allow a technician to overlay two prints and be able to see clearly if they line up and match one another, making certain that each point of comparison is identical on each print\(^3\).

**Methods of Fingerprint Identification**

Now that the history of fingerprint identification has been explored, it is necessary to understand what is meant when two prints are a match and what a technician looks for on each print to begin comparison. There are many different identifying markers that are used to help classify and identify fingerprints. The current system that is used consists of three major types of patterns that can be broken up into several more specific subdivisions. The three main categories include arches, loops and whorls\(^3\). Arches can be of two types, plain and tented, as seen below in Figure 1. Loops also consist of two subdivisions; ulnar and radial (Figure 1). The final category is known as whorls and is divided into four subdivisions; plain, central pocket, double look and accidental (Figure 1)\(^3\). These classifications are the first level of sorting used to differentiate one print from another, both manually and within AFIS databases.

![Figure 1 - First Level Fingerprint Classification](image)
Arches are a classification of fingerprints that are characteristically identified by their overall mountainous appearance. Ridges found in this type of print are generally continuous from one side to another, with a peak being found in the middle of the print. Ridges found near the bottom of the print peak very slightly and may even seem to be straight lines across the print. Tented arches have ridges that do not flow as smoothly from one side to another and have a more defined center peak. Tented arches can display a nearly vertical ridge at the core of the print emphasizing the tent-like nature of this pattern. Loops are overall characterized by ridges flowing from one side of the print upwards towards the center before looping around the core and sloping back towards the point of origin before reaching the other side of the print. The ridges that make up the core of a loop print begin and end on the same side of the print creating the telltale loop that this pattern is known for. The differentiation between radial and ulnar loops is dependent on which side of the print the loops point towards. Radial loops flow towards the radius bone of the arm or the thumb of the hand and ulnar loops flow towards ulna bone or the pinky finger. Plain whorl patterns are characterized by the presence of two deltas on opposite sides of the print between which a complete circuit exists. Central pocket loops can look similar to loop patterns but have a distinct center circuit that makes it characteristic of a whorl pattern. Double loop whorls consist of two loops that point in opposite directions which form around one another in the core of the print. Accidental whorl patterns are formed by a combination of the different patterns described above in a random fashion that does not seem to fit succinctly into any other category.

Once a general classification of a fingerprint is made, more specific and unique characteristics are used to find the individuality of each person’s fingerprints and make positive comparisons. All of these unique markings are a result of the shape, direction, and intersection
of the ridges that make up each fingerprint. There are eight main identifying features that become the so-called “points of comparison” spoken of when two prints are identified as the same. These are known as crossovers, cores, bifurcations or forks, ridge endings, islands or independent ridges, deltas, lakes, and pores\textsuperscript{4}. Visual representations of these features are shown in figures 2 and 3 below. The first identifying feature that can help a technician determine if the print found is a complete or partial fingerprint is the core. This is the center portion of the fingerprint and is typically used as a reference point off of which the locations of other print markers are described. Pores create small holes in the ridge lines of a print and thus often look like voids\textsuperscript{3}. These voids can look like single circular spots in a ridge line or create broken ridges. Differences in appearance of pores on a fingerprint are due to the size and location of a pore along the ridgeline or between ridges in areas known as valleys. Pores are created by the presence of sweat pores on the pads of fingers that help to secrete oils and sweat that are necessary for a print to develop on a surface\textsuperscript{3}.

Ridge endings are the starting point for the identification and location of the rest of the identifying markers that will be discussed. Ridge endings are found at each end of a ridge and must be located in order to differentiate how one ridge interacts with another\textsuperscript{3}. They are particularly helpful in determining the presence of islands or independent ridges. Islands look just as one would expect an island to appear, a small ridge surrounded by much larger ridges\textsuperscript{3}. It is important to understand that an island is an independent ridge which does not seem to fit into the flow of a longer ridge. This becomes important when pores create what are known as dotted ridges, which often look like a series of islands. Islands are the product of a short ridge, where as lakes are the product of the valleys of a fingerprint\textsuperscript{3}. Lakes are formed by a single ridge that branches itself for a short period before converging once again. Once the ridge converges again,
the continuous flow resumes. Divergence points that create lakes can be similar in appearance to what are known as bifurcations or forks. Bifurcations are created when a single ridge splits into two. These resulting ridges do not converge to create a lake, but rather continue as separate ridges until their respective endings. Deltas create what looks like triangular shaped points within a fingerprint. Created by three ridge endings which come together in a way that resembles the delta of a river, the point where a river opens up to a larger body of water. The final identifying characteristic to be discussed is known as a crossover. Crossovers occur when two ridges meet one another, cross and continue on their separate ways. These points look like X’s in the ridge pattern of a particular fingerprint.

Identifying Fingerprint Markers

In order to help identify each point of comparison, a method of ridge counting is employed. This method compares the distance between two points on a single fingerprint by counting the number of ridges between them. Typically the starting point for ridge counting will be the core of the fingerprint. This allows for a relatively centered point of comparison.
Once the core and whatever other point being used are located, an imaginary line is drawn between the two\(^3\). A technician then counts all ridges that pass through or touches the line excluding the two points of comparison. This is done in both prints before the prints can be compared. The number of points of identification that are found in a fingerprint depends on how complete the fingerprint is and how clear the image or lift is\(^3\). Just because a print is not complete, it does not mean that it cannot be used in court. Though it was once common practice that there had to be a minimum of twelve points of comparison for a proper match to be found, these standards are no longer in place\(^3\). Technicians are now encouraged to find as many points of comparison as possible to identify a positive match. This does not mean that only a few markers will be sufficient, but lessens the exclusion of partial prints for comparison\(^4\). It is important to note that though there may be several identical points of comparison, one single point of difference is enough to find that two prints are not a match\(^4\).

AFIS databases allow for another level of comparison that manual comparison is not capable of. When a fingerprint is entered for comparison, more than one possible match appears once the search is complete. Within the list of possible matches that appears, each print has some level of similarity between the reference and database prints\(^4\). This is given as a percentage along with the file that accompanies each fingerprint. Percentages are helpful, particularly when a complete print was not collected, to narrow down the suspect pool to a small list of possibly ten people\(^3\). Percentages also provide supporting evidence when a fingerprint comparison is used in court. These percentages not only show how closely related one print is to another but also the likelihood of another print being a closer match\(^4\). Prosecutors and jurors find this level of proof reassuring when presented in court because it lowers the possibility that the print came from a different source than the defendant. The problem with this is when
there is not a full print and a list of possible suspects is generated\(^3\). If the police have a suspect in mind who happens to be on the list of possible matches, police can become blind to the fact that there could be other suspects and could potentially arrest and prosecute the wrong person\(^3\).

**Case Studies in Fingerprint Identification**

*Mass-Fingerprinting*

One of the most unique and interesting cases of the use and identification of fingerprint evidence was in the case of Julie Anne Devaney\(^5\). It began on the night of September 15, 1948 in the town of Blackburn, Lancashire, U.K. One of the night nurses at Queen’s Park Hospital was making her rounds through the children’s ward when she noticed one of the patients was no longer in her bed\(^5\). Beside the bed was a large glass container of sterile water but nothing else seemed out of place. The body of three-year-old Julie Anne Devaney was found just an hour and a half after the alarm was raised on the grounds of the hospital. She had been sexually abused and beaten about the head with several heavy blows\(^5\). Little forensic evidence was available other than a few sets of prints on the water jug and some footprints left on the freshly waxed floors. It was clear that the killer had entered the ward and made his way to several cots before reaching Julie’s, picking up the water jug along his way\(^5\). This meant that at least one of the sets of prints had to be those of the killer.

Since there were no identifying features of the fingerprints, police were left with no leads. They chose to begin what would be the first and most expansive mass-fingerprinting ever completed. It began by collecting prints from those that had some legitimate reason to be in the ward or to have handled that water jug. A total of 642 sets of prints were collected and police were able to eliminate all but one set of prints collected from the jug\(^5\). This set had to belong to
the killer. From here, police printed over 45,000 people over the age of 16 who had been in the
town on the night of the murder but still were not able to find a match\textsuperscript{5}. Their final effort was to
check ration books, which at the time allowed citizens to access essential foods during war times.
Another 200 sets of prints were discovered that had not been collected the first round. Finally
the 46,253 set of prints compared was found to be those of the killer, a 22-year-old named Peter
Griffiths\textsuperscript{5}. He was arrested and it several other pieces of evidence were found that tied him to
the murder. He was sent to the gallows exactly six months after Julie was killed.

This case shows not only the power of persistence in criminal investigation but also the
power of fingerprint evidence. Had it not been for the efforts of the police at the time the killer
may never have been apprehended. The day and age in which forensic identification currently
stands would never see an effort like this to identify a single set of fingerprints. Most
investigators would take the prints, run them through AFIS, and hope for a match. A mass-
fingerprint effort would not be undertaken to find the killer as there was at the time of this case.
Part of the reason for this is that there are many issues being raised about whose fingerprints
should be in these databases and who should have access to the prints. This controversial issue
does not seem to have a clear answer, as shown here one can see the power fingerprint
identification can have in criminal investigation.

\textit{Richard Ramirez – The Night Stalker}

Beginning in June 1984 until August 1985, the citizens of Los Angeles were terrorized by
a man known as the Night Stalker who was raping and killing women throughout the city\textsuperscript{6}.
Women were being brutally raped and killed by a man that seemed to elude the police at every
turn. It was clear that this offender was careful not to leave evidence behind or to make sure that
any evidence that he took away from the scene, such as a car or murder weapon, would be disposed of leaving no traces back to him. By the time that the offender was captured, he had more than a dozen victims and nearly as many surviving victims. If it had not been for one crucial mistake made at his first fatal crime, it is possible that Richard Ramirez may never have been held responsible for his crimes. There is no doubt that Ramirez committed crimes before his June 28, 1984 robbery and murder but it is believed that this was his first murder, a crime that likely fueled his need for more victims.

On that fateful night in 1984, Ramirez was out late looking for an easy target to rob for valuables. He was a junkie looking for money to make his next score. He happened upon Glassel Park, a small apartment complex where 79-year-old Jennie Vincow lived. Noticing that her window was open because it was a warm night, Ramirez saw an easy target. In an attempt to enter by removing the screen from the open window, Ramirez encountered difficulty because he was wearing gloves. Not thinking, he removed one of his gloves and was able to remove the screen, leaving behind fingerprints. He entered the apartment and finding that there were no valuables to steal, he began to stab Vincow repeatedly. This excited him and he had sexually violated the corpse before leaving and returning the screen to its rightful place. The following day, after not hearing from his mother, Jack Vincow, went to check on his mother. He entered her apartment to find her dead in her bed and called the police.

There was little that the police could do in an effort to bring the suspect to justice. Little forensic evidence was present, and the fingerprints from the window sill had no identifiable matches. The case essentially went cold until eight months later when Ramirez’s other killings began. It would not be until his last attack that Ramirez would find his downfall and be brought to justice for his crimes. A teen who witnessed the last crime was able to write down the license
plate number of Ramirez’s car, which police were able to locate\textsuperscript{8}. In the car, they found several sets of fingerprints which Los Angeles police were able to run through their new and recently updated AFIS system\textsuperscript{7}. The system brought back a match within minutes identifying Ramirez as the murderer and linking him to the Vincow murder. Ramirez was tried, convicted, and is currently serving a life sentence in prison\textsuperscript{6}.

This case shows just how important one fingerprint can be. Had it not been for his difficulties removing the screen from Vincow’s window, Ramirez may have never been connected to that original murder. This also brings up the important idea that though a match may not be initially found, investigators should not put the case aside believing that it will never be solved. Throughout most jurisdictions including the federal government, fingerprints from unsolved cases are also placed in AFIS. These prints are run for comparison with all submitted prints, allowing for the linkage of crimes that may have occurred in different cities, states and sometimes even countries. There have been other cases like the Vincow one in which prints from previous cases are linked to newly entered prints allowing for justice to be brought years later. This is possibly the biggest advantage to the use of systems such as AFIS.

\textit{Atlanta Twin Murder}

On a Friday evening in July of 2008, 40 year-old preschool teacher Genia Coleman was waiting to pick her daughter up near a transit station in Gwinnett, GA\textsuperscript{9}. Witnesses described a black man wearing a white t-shirt with green sleeves carrying a backpack come up to the car in an attempt to carjack Coleman\textsuperscript{9}. The attempted carjacking turned to murder when Coleman was shot by the attacker who fled the scene. His image was captured on surveillance cameras in the area, showing a man matching witness descriptions fleeing from the area\textsuperscript{10}. Investigators
believed that they had the evidence that would definitively identify their killer, DNA from a cigarette butt left at the scene. Little did they know that this evidence would only prove to turn the case into a mystery of sorts.

The DNA evidence returned a match to a previously convicted man named Donald Smith, convicted on drug-possession charges. Donald was arrested and presented with the evidence and video footage the police had collected. He was stunned by the accusations and immediately claimed it was his twin Roland who had committed the murder. In the process of a probable cause hearing, forensic expert Bradley Pearson said that there is a one in 10 billion chance that two people would have the same profile. With only 6.8 billion people on the earth at the time, it was improbable that there would be another person with the same DNA profile. Pearson went a step further to clarify that in the case of identical twin males would have identical profiles. The police went back to the evidence they collected from the original crime scene and reexamined the fingerprints collected. In the mean time, Ronald was located and brought in for questioning. When presented with the evidence, Ronald admitted to the shooting and attempted carjacking. Analysis of the fingerprints collected and those belonging to Ronald showed that they were a match.

This particular case is a perfect transition into the next sections of the paper. Investigators learned that though DNA was the new and emerging technology of the time, it is not always the best way to make identifications. If police had not been willing to listen to Donald’s claims that his twin brother had committed the crime, the wrong man may have been tried and possibly convicted. Investigators initially failed to look beyond the DNA evidence because they believed that there could be no better method of identification. The case of twin suspects shows that though fingerprint identification is an older method, it is certainly not
History of DNA Identification

Before the 20th century, scientists could only imagine and speculate about what it was that held the instructions for all life on earth. Gregor Mendel was the first to put forth a theory of heredity in humans in the late 19th century. His theory of genetics was so unprecedented for the time that it took many years before scientists rediscovered his work in the course of what they believed was “original” work. Though scientists throughout the world now understood how heredity and genetics worked, not until 1935 the blueprint for these concepts was isolated. In this year, a scientist by the name of Andrei Nikolaevitch Belozersky isolated Deoxyribose Nucleic Acid, DNA. Not until almost twenty years later, in 1953, James Watson’s and Francis Crick’s manuscript was published describing the double stranded, helical, anti-parallel structure for DNA. Throughout the 1960s and 1970s there was significant advancement in the field of genetics and study of DNA. Scientists were continually hoping to make discoveries that would help them understand how this small molecule is able to hold all of the genetic material for a human being.

In 1958, DNA polymerase was discovered and isolated, enabling DNA to be made in a test tube. Eight years later, in 1966, the genetic code was “cracked” allowing scientists to understand that it was just three nucleotides, named a codon, which determined each of the 20 amino acids. This discovery enabled scientists to model how the DNA sequence, comprising of just four nucleotides (Adenine, Guanine, Cytosine, and Thymine), coded for the twenty amino acids that formed hundreds of proteins in the human body. There were other discoveries during
this time that showed the polymorphic nature of enzymes and other proteins in the body. The full impact of these discoveries would not be understood until years later when DNA could be better analyzed and the nature of polymorphism understood\textsuperscript{13}. Polymorphism accounts for the simultaneous occurrence of two different forms of an enzyme or other protein. Polymorphisms would become the basis of DNA typing that is currently used as evidence in court\textsuperscript{2}.

By 1972, successful cloning experiments had been performed in California but it would not be until four years later that David Botstein would make steps towards DNA replication and typing as it is known today\textsuperscript{13}. Botstein found that when restriction enzymes are applied to DNA samples of several different individuals, the resulting fragments of DNA could be drastically different from one person to another\textsuperscript{1}. These differences in DNA fragment lengths would come to be known as restriction fragment length polymorphisms (RFLPs). Polymerase chain reaction (PCR) was developed in the early 1980s by a group of scientists working at Cetus Corporation in California\textsuperscript{2}. This was a technique that allowed for the multiplication of DNA sequences and at the time was called the “most revolutionary new technique in molecular biology in the 1980s”\textsuperscript{2}. Sir Alec Jeffreys was the first to develop a DNA profiling test to identify individuals by the middle of the decade\textsuperscript{1}. His method involved detection and identification of multilocus RFLP pattern. It was only a couple of short years later that this process of genetic fingerprinting entered the courtroom\textsuperscript{1}.

The following few years revolutionized the way that DNA evidence was used in the courtroom through advancements in the available technology as well as precedent setting cases. The first case in which DNA evidence was used proved to the scientific and legal communities both the exonerating as well as the convicting qualities that this type of evidence could provide\textsuperscript{1}. In this case, DNA was used to convict Colin Pitchfork of the murders of two young girls in
England after first exonerating an innocent suspect. Henry Erlich became the first to develop a commercially available PCR typing kit specifically for forensic use. He also developed other techniques that could be used for forensic and clinical applications. In People v. Pestinikas, PCR-based DNA testing was used for the first time in court. The application of this technique confirmed that two different samples that were taken during the autopsy were indeed from the same person. This evidence was accepted in civil court and was the first DNA evidence used in the United States. The year after this admittance into civil court, DNA profiling was used for the first time in criminal court, to convict Tommy Lee Andrews of a string of sexual assaults in Florida. By the end of the 1980s, DNA admissibility was being seriously challenged. New York v. Castro set into motion events that led to a call for certification, accreditation, standardizations, and quality control guidelines both for the general forensic community as well as DNA laboratories.

In the 1990s research was being conducted on new methods of DNA typing for forensic use. As a further response to concerns over the practices of forensic DNA typing, particularly in the areas of analysis and interpretation of results, the National Research Council Committee on Forensic DNA published DNA Technology in Forensic Science. This put forth technical and statistical standards for DNA use in forensic science. Thomas Caskey was the first to suggest the use of short tandem repeats (SRTs) for forensic analysis. Based on his research, both Perkin-Elmer and Promega simultaneously developed commercial kits for STR DNA forensic typing with the help of Roche Molecular Systems. In the years following Roche Molecular Systems produced a list of five additional markers to be used in typing with the original commercial kits. Because of much advancement in just a few short years, in 1996 there was a second National Research Council Committee on Forensic DNA. This committee published The Evaluation of
Forensic DNA Evidence which elaborated on developments since the first publication and modified some of the recommendations made in the 1992 edition\textsuperscript{13}. The same year mitochondrial DNA was admitted for the first time as evidence in a U.S. court\textsuperscript{1}. By the close of the decade, the National Integrated DNA Index System (NIDIS) was formed that allowed for interstate cooperation in linking and solving crimes\textsuperscript{2}.

In doing research, there was little material found on the advancements made in DNA identification since the year 2000, though it has made great strides in the courtroom and laboratory. The Human Genome Project brought to light the entire genetic code by discovering what genes code for within humans. This has helped forensic technicians look for and understand many of the distinct features of DNA profiles\textsuperscript{13}. This understanding helps isolate distinctive DNA abnormalities and markers that are related to disease and genetic defect. These types of markers help to include and exclude suspects more quickly in an investigation if one of these is identified in a DNA sample\textsuperscript{13}. DNA identification has also branched out within the legal world in recent years. Major natural disasters and terrorist attacks have seen DNA used as a method of identification when traditional methods fail\textsuperscript{14}. The reason for this is it takes only a small sample of DNA to be isolated for identification. The attacks on September 11, 2001 were an exemplary indication of where DNA identification is headed. This technique of identification provided identifications for many people and closure for families that may have never otherwise known what happened to their loved ones. The United States military, since 1992, has been collecting blood and tissue samples of all enlisted service people. It is part of an initiative that was begun to build a “genetic dog tag” database to help in the identification of service people who are killed in war\textsuperscript{2}. 

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Just as with modern fingerprint identification, modern DNA identification has become a partially computerized analysis. There is more technology available that takes the results of the below described methods of DNA typing and creates a computerized output. The Short Tandem Repeat (STR) method is one of the most commonly computerized methods of current DNA identification available\textsuperscript{13}. As the outputs of analysis become computerized, so does the storage systems for DNA profiles. The current federal database in use is known as the Combined DNA Index System (CODIS)\textsuperscript{13}. Just as with fingerprint databases, not all states use the same particular software and thus there are still compatibility issues between local, state, and federal systems\textsuperscript{2}. CODIS is currently only accessible to certified labs and is under the control and maintenance of the FBI. This system stores STR profiles for all samples entered into the database and a match is based on all of the similar loci between the reference and unknown samples\textsuperscript{14}.

**Methods of DNA Identification**

There are currently many options for the analysis of DNA samples collected at crime scenes. There are advantages and disadvantages to each method and thus the circumstances of each sample must be evaluated before testing can be completed. No matter what method is used, it is important for laboratory technicians to carefully document practices completed and the handling of evidence so there will be no objections when evidence is presented in court. What is to follow is a brief description of the methods of analysis that are currently available and the advantages and disadvantages associated with each.
Restriction Fragment Length Polymorphism (RFLP) was the first accepted method of identification and has the highest certainty discrimination per loci\textsuperscript{13}. Analysis of this type centers on the determination of variation in length of a defined DNA fragment. Power of discrimination is a measure that determines how effectively two samples are differentiated\textsuperscript{14}. There are two main factors that contribute to this measurement. The first factor is that there are many loci that have been determined useful for RFLP analysis. As a result, the more places that are available to look for differences, the greater chance of finding difference between two samples\textsuperscript{14}. There are currently 15 loci that are available for comparison by forensic DNA technicians. The other factor is that the loci chosen have been found to contain hundreds of variations throughout the population\textsuperscript{13}. This increases the chances that samples from different individuals have significant differentiations.

Once DNA samples have been collected from the scene, the victim, and any suspects, the DNA is treated in a solution with a variety of molecular scissors, known as restriction enzymes\textsuperscript{14}. These scissors cut the DNA at specific locations along the sequence creating restriction fragments. Each enzyme cuts in a different location creating many different possible loci analyzed by RFLP\textsuperscript{14}. Though each laboratory can chose to use a different enzyme in their analysis, the two most commonly used enzymes are HinfI and HaeIII\textsuperscript{14}. The resulting fragments are loaded into lanes on an agarose gel and a current is passed across the gel. This causes the fragments to move across the gel, separating each based on length. The longer the fragment, the closer the resulting band will be to the place that the sample was loaded\textsuperscript{14}. Resulting bands formed by the fragments are then compared to one another to make identification or find dissimilarity between two samples. The resulting image of the bands on the gel is known as an
autoradiograph and is shown below in Figure 4\textsuperscript{14}. This method is preferred for the determination of whether a sample contains more than one person’s profile.

![Autoradiograph](image)

**Figure 4\textsuperscript{14} – RFLP Autoradiograph**

Though RFLP has many promising aspects, there are still restrictions and limitations to this method of DNA typing for forensic use. The DNA that is analyzed by this method must be of better quality than is typically found during criminal investigations\textsuperscript{13}. There also must be a large sample of DNA available in order for analysis to be done, typically visualized as enough to cover half of a dime. This restricts many instances when there is often just a single drop of blood available for analysis\textsuperscript{13}. Another common drawback to RFLP analysis comes into play when samples are to be analyzed by several different laboratories. Since not all labs use the same restriction enzymes, different resulting bands will be created by each of the enzymes\textsuperscript{14}. It will then be important for technicians to independently verify the origin of the samples and possibly run multiple tests to verify results\textsuperscript{14}. No matter what enzymes are used, the resulting analysis will not change. Differences and similarities between two samples will be found the same with the use of any enzyme and analysis of any loci\textsuperscript{13}.
**PCR**

Polymerase Chain Reaction (PCR) is a general technique that is used throughout the scientific world to increase the amount of a specific section of DNA, also known as DNA amplification. It is generally accomplished with only a small section of DNA and is completed with high fidelity to the original fragment. Amplification of the DNA sample by this method increases the number of copies of DNA exponentially, as shown in Figure 5 below. For further analysis of a segment of DNA, that would otherwise not be analyzed because of the amount present, is possible. This method is not typically used in conjunction with RFLP analysis because RFLP fragments are too large to be faithfully amplified through PCR methods. Of the techniques that are available for further analysis, the number of loci is small and the variability at each locus is minimal. This typically results in low power of discrimination, and as a result a sample of limited quality and quantity. There is current research on several additional loci that could be useful in making identifications with the help of PCR analysis. A short description of some methods of analysis accompanying PCR follows.

![PCR Amplification of DNA](image)

**Figure 5** – PCR Amplification of DNA
The first method for forensic analysis and use of PCR-amplified DNA was the HLA DQα system. Analysis of a fragment of DNA using this method is done with probes. Each probe used specifically targets a different portion of the fragment and targets one of six common DQα alleles present within the population. Results of this test are seen as a series of blue dots on the test strip, shown in Figure 6 below. Comparison of the pattern and intensity of these dots determines the similarity or difference between samples. These six alleles create 21 possible genotypes and thus have a low power of discrimination. One advantage to this method of comparison is that there is only a small sample size necessary for analysis.

Figure 6 - HLA DQα/HLA DQA1 Dot Blot (dots are blue in lab testing)

The current method of typing using this gene cluster is known as DQA1. This came about as an improvement to identification because of the ability to subdivide several of the alleles. This creates 42 detectable types, increasing the power of discrimination slightly. The resulting analysis and determination of similarity and dissimilarity remain the same as with the DQα method.

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AmpliType© - “Polymarker”

AmpliType© PM system, typically known as polymarker, is an expanded analysis of the HLA DQα method of typing\textsuperscript{14}. The purpose of developing this method was to increase the power of discrimination while retaining the advantages of PCR technology. This method analyzes more than one marker at the HLA DQα site, even though each of these markers contains less variation\textsuperscript{14}. One of the major disadvantages of this method is that interpretation becomes difficult when the sample being analyzed comes from multiple sources. The final results of this test are similar to above in that a series of blue dots on a typing strip are obtained and compared to determine similarity or dissimilarity between samples, shown in Figure 7 below\textsuperscript{14}.

![Figure 7 - Polymarker Dot Blot (dots are blue in lab testing)](image)

\textit{D1S80}

D1S80 refers to the locus of DNA that is being investigated in this method of analysis. Identification is more similar to RFLP, but because of the small fragment length analyzed, it is amendable to PCR amplification\textsuperscript{14}. Throughout forensic literature, this method is known as
Amplified Fragment Length Polymorphism (AFMP). Analysis and differentiation between samples is completed on the basis of the number of tandem repeats present within the sample\textsuperscript{14}. Tandem repeats are short sections of DNA, typically only a few base pairs in length, that varies in the number of repeats from person to person. The locus, or segment, that is being investigated in this method typically has a number of repeats from 14 to 41\textsuperscript{14}. Though this technique combines all of the advantages of PCR technology, there are problems inherent with this locus. Two alleles that are common among people of some racial groups can cause the significance of the test to be called into question\textsuperscript{14}. Low power of discrimination is another problem that is common to all PCR analysis techniques.

Use of this technique does not require probes to be used as they in RFLP analysis. This is because before analysis is completed, the sample is purified to remove excess reagents from the PCR reaction\textsuperscript{14}. The loci detected are referred to as discrete alleles because they can be compared directly to a standard ruler of all possible alleles, known as an allelic ladder. This ladder is run on the same gel as the samples being analyzed and the resulting gel looks similar to results from RFLP analysis\textsuperscript{14}. This can be seen in Figure 8 below where lanes 1, 4, 7 and 10 are the allelic ladders.

\textbf{Figure 8\textsuperscript{14}} – D1S80 Stained Gel

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**STRs**

Short Tandem Repeats (STRs) are similar to the D1S80 except that the lengths of the repeats analyzed are shorter\(^{14}\). The number of alleles present within the population varies from 5 to 20 depending on the locus analyzed. Similar to the above method, an allelic ladder is run simultaneously to the samples\(^{14}\). There are many different STR loci that can be chosen within the human genome and multiple loci can be analyzed at the same time. This idea is known as multiplexing and results in saving time, materials, and most importantly sample\(^{14}\). There are two methods of detection, silver-staining and fluorescence. Fluorescence is useful because it allows for detection before and after separation\(^{14}\). The only downside to fluorescence detection is that there is a larger expense associated with this method than other methods. The resulting data from fluorescence detection is shown below in Figure 9 in which 4 different loci are analyzed including the gender loci\(^{14}\).

![Figure 9](image-url) – STR Analysis with Fluorescence Detection
Gender ID

Gender identification is often useful in forensic analysis. This locus is known as the amelogenin locus and is also the gene for tooth pulp\textsuperscript{14}. The lengths of two regions of this locus are shorter in females than in males. When these regions are analyzed, females have only one band that is typically slightly larger than a normal band, resulting from a female’s two copies of the X chromosome that determine gender\textsuperscript{14}. Males have two separate and distinct bands that result from the X and Y chromosomes that determine gender in males.

Mitochondrial DNA

All of the previous methods of DNA identification centered on the use of nuclear DNA, but there has been emerging research of the use of mitochondrial DNA as another possible source of identification. Mitochondrial DNA exists in the mitochondria, one of the many organelles in the cytoplasm of the cell\textsuperscript{14}. This source of DNA is not specific to each person but rather is passed down from mother to child throughout a family. The result of this is that mother and all children contain the same mitochondrial DNA sequence\textsuperscript{13}. This method of identification cannot be used as a definitive and distinctive method of identification but can be used to include or exclude a person into a list of possible suspects. Mitochondrial DNA can be used when there is not a large enough sample or when nuclear DNA is degraded beyond use\textsuperscript{14}. There are many mitochondria in each cell and thus there is the possibility for a larger amount of this type of DNA in a small sample. Mitochondrial DNA is believed to last longer than nuclear DNA and does not degrade as easily\textsuperscript{14}. When mitochondrial DNA is analyzed, two hypervariable regions are analyzed. These two regions, HV1 and HV2, are depicted in Figure 10 below. They are believed to vary between 1\% and 2.3\% in unrelated individuals\textsuperscript{13}. There are few forensic
laboratories that currently use this type of DNA analysis, but research continues to be done to
determine if there are other potential uses for mitochondrial DNA.\textsuperscript{14}

\textbf{Figure 10}\textsuperscript{14} – Locations of 2 Hypervariable Regions of Mitochondrial DNA

\section*{DNA Evidence and the Courts}

\textit{RFLP}

Throughout the history of DNA’s use as forensic evidence, there have been many laws
passed and standards set for the use, admissibility, and rules of evidence. The overall rule or
standard of evidence that the courts rely upon, particularly with the use of DNA, is the \textit{Frye}
Standard\textsuperscript{14}. This precedent was set in \textit{Frye v. United States} which originally dealt with the
admissibility of the polygraph in criminal cases. The standard set regarding scientific evidence
said:

\begin{quote}
\textit{“…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”}\textsuperscript{14}
\end{quote}

There was a corollary added to this standard which added three parts including\textsuperscript{14}:

1. Reliability must be established by experts;
2. Experts must be properly qualified; and
3. Correct procedures must be used.
Beyond this, there were several other federal rulings that added additional restrictions and clarifications to the original rulings. Overall, these court cases and regulations became the Federal Rules of Evidence. These rules are considered to be a looser version of the rules set forth in Frye, stating that if findings are relevant, reliable, and more probative than prejudicial, they can and will be allowed into court. In addition to this standard, there are many states that have added a Relevancy Standard, which means that the evidence presented must be relevant to the issue of the case being presented.

The first court case in which RFLP evidence was used was in State of Florida v. Andrews in 1987, which dealt with accusations of sexual assault. Andrews was convicted of the crime after first being acquitted, setting the stage for the use of DNA evidence in criminal court. For many years there were no major challenges to the use of DNA evidence in courts. It was not until 1989 that admissibility and reliability were seriously challenged in People v. Castro. The issue came down to a three pronged test for DNA to be used in court:

1. Is there a sound theory behind DNA testing?
2. Are there techniques for testing capable of producing reliable results?
3. Were the tests performed properly in this case?

It was determined that the third standard in Castro was not met and thus the DNA evidence could not be used. This case put major focus on the accreditation, certification, quality control, and standardization of DNA testing as well as other forensic testing. People v. Axell, in 1991, emerged at a time when the use of population statistics was the center of controversy within the study of DNA. Scientists were in hot debate over whether or not there was the possibility of substructures within the population that could affect the statistical independence of genetic loci used for forensic analysis. This resulted in a practical consequence which held that frequencies of each allele could be multiplied together to give an approximate frequency of the composite
The debate in Axell centered on molecular biology and population issues throughout the hearings. The judge finally determined that the DNA would be allowed as evidence along with the supporting statistical evidence.  

It was also in 1991 that the FBI allowed the use of RFLP analysis. A battle between both sides of the scientific community over the analysis and statistical backing of DNA evidence ensued. The judge in the case ruled in favor of the prosecution and allowed the evidence into trial but still managed to bring to the forefront the issue of analysis and interpretation of results in the context of population genetics. Federal appellate courts were faced with admissibility issues of RFLP DNA evidence in the 1992 case United States v. Jakobetz. The courts ultimately upheld admissibility standards and the evidence was admitted into court, through it did not result in a conviction in the case. The National Research Committee on DNA Technology published a set of recommendations on these issues in the same year. They proposed a “ceiling principle” that was meant to put a limit on the rareness of a DNA profile. The “ceiling principle” was a calculation that factored in the rarity of each loci being analyzed to place an upper limit on the overall rarity of a DNA profile. This principle came under great criticism amongst scientists and thus led to a second committee in 1994. During the time when the statistical basis was being challenged, there were two landmark cases that came before appellate courts of California. These cases, People v. Barney and People v. Howard, had the DNA evidence upheld in lower courts, but when they reached the appellate courts, DNA was challenged. The court chose to bar the use of DNA until the controversy had been resolved. Both convictions were upheld based on other evidence.  

Two further cases during the same time, People v. Pizarro and People v. Wallace, continued the trend of rejecting DNA evidence from the courtroom because of the lack of
continuity in the methods of gene frequency estimates\textsuperscript{14}. Not be until 1994 was this trend changed in the case of People v. Soto\textsuperscript{14}. The “ceiling principle” was a calculation that factored in the rarity of each loci being analyzed to place an upper limit on the overall rarity of a DNA profile. The decision in this case went on to determine that DNA evidence is too relevant in court to be ignored. Though the trend seems to be that most states are in favor of admitting DNA evidence along with statistical probability, there are two states that have not yet allowed statistical evidence into the courts\textsuperscript{13}. Arizona has consistently moved away from the use of statistical evidence in courts, though this seems to be changing. Based on the recommendations and guidelines put forth by the second National Research Council, Arizona Supreme Courts are likely to begin allowing statistics into the courtroom\textsuperscript{13}. Minnesota has also excluded the use of statistical data from the courtroom on all scientific evidence, not just DNA. Their courts seemed to reverse themselves in 1994 in considering the cases of State v. Bloom, State v. Bauer, and State v. Perez\textsuperscript{14}. They seemed to favor the decision of the National Research Council placing a “ceiling” on statistical evidence. The ruling stated that there was the need for a “DNA exception” to the use of statistics in courts, allowing the statistical probability of a DNA profile to be used as evidence\textsuperscript{14}.

**PCR**

PCR technology has not encountered the trials and tribulations that RFLP has faced in the court system, though it is relatively new. Part of the reason that this technology has been better received is that it focuses on only one genetic marker not several, thus removing population genetics issues related to RFLP. This is not to say that PCR has encountered no challenges, but rather the challenges it faces are of a different focus, the application of the technology. People v.
*Dotson* is one example of PCR technology being used as an exclusionary tool\(^{14}\). In 1977, Dotson was convicted of rape based on witness identification, through serological identification was inconclusive\(^{14}\). In 1985, the witness recanted her identification and claimed that she had consensual sex with her boyfriend. PCR typing was used and definitively found that Dotson was not the contributor of the semen sample but the courts refused to admit this evidence to release him\(^{14}\). He was later released through clemency granted by the governor.

It was not until 1989 in *People v. Martinez* that PCR began to encounter its early objections\(^{13}\). Testing showed that there was a semen sample from someone other than the defendant on the panties from the victim in post-conviction review. Because of the newness of the technique and apparent lack of scientific community-wide acceptance, the judge refused to overturn the conviction\(^{14}\). The following year, the judge in *People v. Mack* came to the same conclusion that PCR testing was not generally accepted by the forensic community and would not allow the evidence\(^{14}\). A California judge finally allowed PCR evidence to be used in *People v. Quintanilla* in 1991\(^{14}\). DNA was used to exclude the initial suspect and convict a second. Though admitted, the court refused to comment on the admissibility issue claiming that it would be an error to do so\(^{14}\).

By October of 1994, it was generally believed that the debate over DNA was over. An article published in *Nature* by Eric Lander, a member of the original National Research Committee, explained many of the faults with the way the committee’s recommendations had been interpreted\(^{13}\). He stated that the “ceiling principle” was not meant to be a way of discounting previous methods of determining statistical probability of a certain genetic profile, but was rather meant to be a conservative limit as a second alternative\(^{14}\). It was generally believed that what little substructuring exists did not significantly alter the determination of the
rareness of a particular profile in the general population\textsuperscript{14}. This was not to say that the “ceiling principle” would continue to be used. In 1996, a second committee was convened that dropped the use of this principle and rather suggested alternatives that focused on population genetics and statistics\textsuperscript{14}. The committee’s report resulted in courts dropping many of their issues with DNA evidence. What courts now must realize is that DNA evidence must be evaluated for each case on its own particular merits, but general reliability can be within grasp.

In 1992, The Innocence Project was begun as a non-profit legal clinic started by Barry C. Scheck and Peter J. Neufeld\textsuperscript{19}. The clinic is run through the Benjamin N. Cardozo School of Law at Yeshiva University. It has since become a national litigation and public policy organization that works to exonerate wrongfully convicted persons through the use of DNA analysis\textsuperscript{19}. Since the project began, there have been over 280 overturned convictions with almost 40\% of these cases resulting in the conviction of the true perpetrator through the DNA analysis\textsuperscript{19}. Overturned convictions have been won in 35 states as well as Washington, DC\textsuperscript{19}. The three states with the highest number of overturned convictions are New York (27), Illinois (34), and Texas (43)\textsuperscript{19}. Though these statistics show the brighter side of overturned convictions, unfortunately it has not always been so uplifting. There have been 17 cases so far in which an innocent person has been put to death before DNA was able to exonerate him/her\textsuperscript{19}. About 70\% of the cases investigated through DNA analysis dealt with convicts who are members of minority groups\textsuperscript{19}. The average prison sentence served by those whose convictions were overturned currently stands at 13 years\textsuperscript{19}. 

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Case Studies in DNA Identification

Though there are programs such as the Innocence Project that work to exonerate wrongly convicted murderers, DNA databases such as CODIS have allowed for the arrest and convictions of criminals who otherwise would have gone free. Similar to how fingerprints from unsolved crimes are stored in AFIS for possible later identification, a practice is upheld within CODIS databases.

Gary Ridgway - The Green River Killer

Throughout the 1980s and 1990s there was a string of rapes and murders in the Seattle-Tacoma area. The victims were women, typically prostitutes, who would vanish sometimes days apart and other times only a couple each year. They were all raped and manually strangled. Many of the early victims were found in or near the Green River, gaining the offender his name. The only problem with locating this offender was that there little forensic evidence left behind. At the time, in the early 1990s, DNA identification was still a new procedure and there were many who were skeptical of its use and reliability. The police at the time suspected that Gary Ridgway was responsible for the crimes but they lacked the physical evidence to arrest him. The case basically went cold for many years.

It would not be until 2001 that forensic investigators decided to reopen the case and test the DNA that had long ago been collected and stored. The samples were tested with both PCR and STR technology and compared to known reference samples from Ridgway. The samples matched and the detectives were overjoyed. They would finally be able to see justice brought to the many victims and families affected by these crimes. Ridgway was arrested and subsequently admitted to 48 murders. He was sentenced to 48 consecutive life sentences for his
crimes. There are many theories that are out there about the Green River Killer. Some people, including police in Washington, Oregon, California, and British Colombia, believe that there are more victims out there that may never be identified. Others believe that it was not just Ridgeway but that there are several Green River Killers that are responsible for these crimes.

Whatever the truth is about other victims or multiple offenders, it is clear that without DNA there would have been no conviction or closure for any of these cases. Confidence in the ability of DNA to positively identify suspects and offenders allowed investigators to give the case another look and ultimately solve 48 murders. This is also a testament to the ability of properly stored DNA evidence to withstand the tests of time. There were no problems of degradation of the DNA within the samples that had been collected up to two decades before testing occurred. This is not always the case of proper storage and handling of DNA evidence. As will be seen in the following case, mishandling of DNA evidence can lead to major issues once the trial begins and evidence is more closely scrutinized.

**OJ Simpson**

A barking dog was the only thing that alerted neighbors to a problem on June 12, 1994. A concerned neighbor went to check on the dog and found the bodies of Nicole Brown Simpson, former wife of basketball star OJ Simpson, and her friend Ronald Goldman. When police arrived they were greeted with the gruesome scene in the courtyard of Brown’s condominium in Brentwood, California. One of the first suspects that came to investigators was Brown’s ex-husband, OJ Simpson, though at the time they had no evidence to arrest him. Extensive evidence collection was undertaken by forensic technicians and investigators, including most
notably many blood samples collected from sources at the crime scene as well as later in Simpson’s home and car\textsuperscript{23}.

RFLP analysis was conducted on a blood drop found leading away from the bodies, because it was the biggest of the drops recovered, and was found to contain genetic markers consistent with OJ Simpson\textsuperscript{23}. Based on the analysis there was a one in 170 million match in DNA on this drop alone\textsuperscript{24}. Several other drops found leading away from the bodies were analyzed with PCR technology and a one in 5,200 match to Simpson was found\textsuperscript{24}. This evidence, along with a cut Simpson had on his finger when he was located and spoken to, was enough to convince investigators that they had the right man. There was other DNA evidence collected and analyzed showing Simpson’s as well as Brown’s and Goldman’s DNA\textsuperscript{25}. These samples were collected from bloody gloves found in the backyard of the condo, bloody socks found at the foot of Simpson’s bed, and several spots in Simpson’s Ford Bronco\textsuperscript{25}.

By the time that the case made it to trial, there was such a preponderance of evidence that few people doubted Simpson was responsible for the murders. The only problem was the defense brought to light serious patterns of contamination throughout the Los Angeles Police Department’s PCR testing\textsuperscript{23}. There were other allegations of contamination with the RFLP analysis, but since the technique itself was less vulnerable to contamination not much came of this issue\textsuperscript{25}. Allegations made by the defense included that investigators planted the blood evidence, something that was improbable because of the time when crime scene samples were taken and when reference samples were taken from Simpson\textsuperscript{24}. There were more claims made by the defense and other information brought to light once the trial began\textsuperscript{23}. This evidence, combined with the push the defense made about the gloves prosecutors claimed were worn by the killer not fitting, Simpson was acquitted of the murders of Brown and Goldman. It is
important to note that when this case went into civil court, Simpson was convicted of his crimes and required to pay restitution to the families of the victims\textsuperscript{25}.

This is one of the unfortunate cases of DNA identification. The evidence was present and conclusive, but the practices that obtained that evidence were questionable and thus justice was not served. This only served to reinforce the need for better practices within laboratories on collection and analysis of DNA evidence. The case developed during a time when courts were working to establish standards and quality controls for the use of DNA. Since then standard practices have helped to eliminate many of these issues and there are fewer instances when things like this can happen.

\textbf{The C.S.I. Effect}

The C.S.I. effect is a phenomenon that has grown significantly over the last few years as the number of crime shows increases\textsuperscript{26}. These popular shows, including the CSI and Law and Order families, Criminal Minds, Castle, NCIS, and The Mentalist amongst others, have not only brought the abilities of the field of forensic science to the general public, but also raised expectations. There is no doubt that the science shown on these shows, though based in fact and real practice, fails to meet the conditions of the real laboratories\textsuperscript{26}. Many differences can be identified between the practices on these shows and the inner workings of a forensic laboratory. One of the most significant is that the scientists working in the lab do not go out into the field to search for and collect evidence, nor do they work side by side with detectives throughout the case and in the interrogation room\textsuperscript{26}. Another common misconception that results from these shows is the time period necessary for the processing and analysis of evidence, particularly DNA
and fingerprint evidence. Shows depict that evidence can be processed and analyzed in a matter of hours, sometimes up to a day, but this cannot be achieved in a regular laboratory.

With the advent of DNA identification, laboratories quickly became backlogged in the analysis of evidence, most especially DNA evidence. Typically evidence is processed in the order in which it came into the lab, with few exceptions in cases of high-profile crimes. Even once evidence reaches the top of the list, analysis often takes several weeks to be completed. PCR techniques take time to be properly completed and to yield samples that are clean and large enough to be further analyzed. It is also often the case that an item with possible DNA evidence contains some other type of trace evidence. In situations like this, the collection of trace evidence comes before DNA identification in priority. This can lead to the hold up of DNA identification if trace technicians are busy or otherwise unable to properly remove trace evidence. DNA profiles that have been recovered and analyzed can also be held up before identification can occur. It can take days and even sometimes weeks for a DNA profile to be run through CODIS if a reference sample is not available for immediate comparison. This is also true of fingerprints collected from a crime scene. Because of the thousands of entries in AFIS, identification without a reference can be a long and time-consuming process. This is typically why many cases remain open for months and sometimes years if waiting on DNA or fingerprint identification.

Beyond the time expectations that the public unrealistically gains from these shows, there is also the expectation that definitive forensic evidence will be available and present at every scene. Along with this expectation, these crime shows make it seem like there is minimal evidence collected at each scene and that there will always be that one piece of evidence to crack the case found at every scene. This expectation is unrealistic because there is the possibility of
hundreds of individual pieces of evidence that are collected from each scene. Until analysis is completed, there is no indication about what is important and what is not. This also results in a great deal of time necessary to analyze each piece of evidence and determine its significance within the scope of the investigation.

Advancements in technology are a controversial issue that has been brought to light in the context of crime shows. There is often the use of new and unsupported technologies in forensic investigation. The use of these techniques can lead jurors to believe that similar technologies are at the disposal of forensic technicians everywhere. This is often not the case, particularly when a particular type of technology does not even exist or is being developed. Related to this is the fact that not all forensic laboratories have the same technological capabilities. There are many labs that do not have large budgets and are not able to perform even some simpler techniques out there because the technology necessary for the analysis is too expensive. Many of these labs outsource some of their analyses to larger and better funded county or state laboratories and sometimes even to the federal government.

When jurors are not aware of these facts, their expectations far exceed what is possible. This has led to numerous acquittals because of the lack of forensic evidence. It is a concerning trend for law enforcement officials and investigators because it can result in dangerous people walking free. One possible way to combat this growing issue is to educate the public on the practices of forensic laboratories. Television producers were behind these initiatives for many years through shows on TruTV and True Crime. These shows included Forensic Files, 48 Hours Mystery, Cold Case Files, Dateline NBC, Unsolved Mysteries, The First 48, and America’s Most Wanted among others. These shows attempted to bring true forensic techniques and applications to viewers while going through the investigations of famous and shocking cases. As the
popularity of fictional crime shows has increased, these shows and networks have lost funding and some have gone off the air. If some of these shows were brought back or fictional shows were to depict events in a more realistic way, manifestations of the C.S.I. effect could be minimized.

A Case Study on the C.S.I. Effect

There have been numerous cases influenced by the C.S.I. Effect since the shows first began to air. This leads to many possibilities from which to choose a case to detail the manifestations. One of the most interesting and controversial cases that is a product of this effect is the recent trial of Casey Anthony. There are many examples of this effect, most particularly in the lack of definitive forensic evidence available for presentation in court and the new technologies that were presented as evidence.

The disappearance of Caylee Anthony was a tragedy that captured news headlines and the hearts of people throughout the country. There was much debate and criticism of her mother, Casey Anthony, for her actions after her daughter went missing. Casey failed to report the disappearance to police for a month telling Caylee’s grandparents that she was with a friend or that she was at the babysitter’s house. There never seemed to be a straight story coming from Casey, who seemed more concerned with her young party lifestyle than with the fact that her daughter had not been seen. Once police became involved, Casey began telling conflicting stories of what happened to her little girl. She first claimed that Caylee was taken by a mysterious nanny and then later recanted that story. It was not until the body of Caylee was discovered just a short distance from her grandparent’s house that suspicions began to rise around Casey.
The investigation concluded with charges being brought against Casey in the disappearance and death of her daughter Caylee. Prosecutors claimed that Casey suffocated Caylee by placing duct tape over her mouth after incapacitating her with chloroform. She then wrapped her in a blanket, placed her in garbage bags and left her in the car trunk before placing her in the woods according to prosecutors. It seemed unfathomable that a mother could do this to her child, and the evidence that investigators were able to locate was consistent with but not definitive of the crime. Investigators and prosecutors went as far as to include air-sampling techniques that had not yet been used in criminal court.

When jurors entered the court room, there seemed to be an expectation of hard facts and convincing evidence that would convict Casey Anthony of the death of her daughter. What they were left with was little more than a circumstantial case that provided evidence that could corroborate the prosecutions’ theory but also could indicate that no crime was committed by Casey. When jurors were presented with air-sampling evidence, little convincing scientific background to stand on existed. Though these techniques had been tested and proved in a laboratory setting, there was no research on real life situations. The evidence had also never before been presented in court and thus there were no precedent setting cases for jurors to refer to. After weeks of testimony, jurors took only 11 hours to bring back their verdict that many expected to be guilty. Spectators and prosecutors were stunned when the verdict was not guilty.

Based on the amount of evidence presented, though circumstantial, linking Casey to the murder of her daughter, jurors were not convinced. This is likely linked to the C.S.I. Effect discussed earlier. When a person enters the courtroom, he or she is not expecting to be presented with a case full of circumstantial evidence and theories. He or she is looking for the hard facts to
back up that story. Prosecutors can no longer rely on heuristics to fill in the blanks and result in convictions. Many now debate whether or not these shows should continue to air. This is a difficult question to answer and there may not be a clear and definitive answer that makes all parties involved happy. What prosecutors must remember when heading into court is that if evidence is not present or conclusive, they will have to fight an uphill battle to gain a conviction.

Conclusion

There can be no doubt in the minds of forensic investigators and the public alike that fingerprint and DNA identifications have helped to advance criminal investigations and lead to many convictions. The field of forensic science, particularly in the areas of DNA and fingerprint identification, has endured many technological advances as well as struggles in the use of evidence in the courtroom. If there had not been advancements made that coincided with technology, our justice system would not be as effective as it is today. Forensic science allows investigators to decode a crime scene and explain what the victim of a crime often cannot. These hard facts that are provided enable prosecutors to present a clear case to jurors. They are then able to make decisions on the guilt or innocence of a defendant virtually free of ethical dilemma, or at least that is the hope. DNA and fingerprint identifications have shown to be a challenge to the ethics free decisions that they were through to provide. This is made particularly evident when the use of computer technology is added to the already controversial technologies themselves.

Privacy issues seem to be the most prevalent of these problems facing DNA and fingerprint evidence and databases in today’s world. Consensus cannot be reached over who should be entered into databases and how their information should be used one it is in a database.
It is likely that agreement on this issue is something that will not be found in the near future. This is particularly due to the continual challenges and options that form around these methods of identification. Whatever the laws are that govern these things, there will be no doubt that identifications made through these technologies are valuable and vital to criminal investigation.

In a day and age of advancing technologies, the field of forensic science should not be so quick to get wrapped up in the newest and “best” technology, but must be careful to ensure that there is data and research to back up the evidence before it can reasonably be brought into court. Prosecutors must be increasingly aware of the bias that jurors have when entering into the courtroom. The C.S.I. Effect has brought an increased desire and search for hard facts to back up the case being made against a person. As a result, there is a careful balance that must be reached between the use of emerging technologies and the gamble of presenting a case with little evidence. No matter what the prosecutors and investigators chose to do, there are no guarantees that the case will end with a conviction. In a situation where there seems to be no clear answer, what must be remembered is that each case is unique and must be approached in that manner to bring justice.
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