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DNA FINGERPRINTING

An Interactive Qualifying Project Report

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ABSTRACT

This IQP explores the science of DNA fingerprinting and the impact it has had on the judicial system. The main techniques for creating a DNA fingerprint, and the proper procedures for collecting and storing DNA evidence to prevent contamination were discussed. The evolution of DNA evidence in the court room was tracked through landmark court cases establishing standards and precedence for admitting DNA evidence. A few sensational court cases were discussed to show the impact DNA evidence has had on the criminal justice system. The effect of technology on society was discussed regarding the ethics of DNA databases and the privacy rights of the DNA donor. Finally the authors drew their own conclusions based on the research performed.

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PROJECT OBJECTIVES

The rationale of this project is to investigate the rising new technology of DNA fingerprinting, and explore its impact on society. The purpose of chapter-1 is to describe the main techniques used to create a DNA fingerprint profile from a sample of DNA. Chapter-2 outlines the forensics involved in DNA fingerprinting including: the proper collection of DNA evidence, maintaining a chain of custody for evidence, and the proper storage of DNA containing evidence. Chapter-3 follows the progression of court room cases that established the standards for admitting complex scientific evidence in courts. Chapter-4 portrays three well known sensational DNA court cases that prove how important this technology can be in solving a case as long as it is performed correctly. Chapter-5 illustrates the importance of DNA databases and the ethics surrounding the privacy rights of the people included in it. Finally, the authors of this IQP draw their own conclusions based on the research performed.

Chapter-1: DNA Fingerprinting Technology

Cody McCormick

DNA is the most accurate means of identification we have to date to differentiate one person from another. DNA is like an organic barcode for every individual, with no two being the same, except identical twins. Since its discovery in 1985, DNA profiling has grown enormously as a science with many new uses including, paternity testing, forensics, and molecular archeology. The purpose of this chapter is to discuss the technology of DNA fingerprinting, to facilitate the later chapter discussions of ethics and laws.

DNA

Deoxyribonucleic acid, DNA, is the basic building block of all cells in the human body (except red blood cells that contain no nucleus). DNA is the molecule containing the blue print that tells the cell how to function. DNA is composed of four bases, adenine (A) which always pairs with thymine (T), and cytosine (C) which always pairs with guanine (G) (**Figure-1**). The sequence of these bases dictates the "information" found in DNA. DNA exists in a double helical structure, whose strands contain alternating sugar and phosphate backbone, with the ladder composed of base pairs.

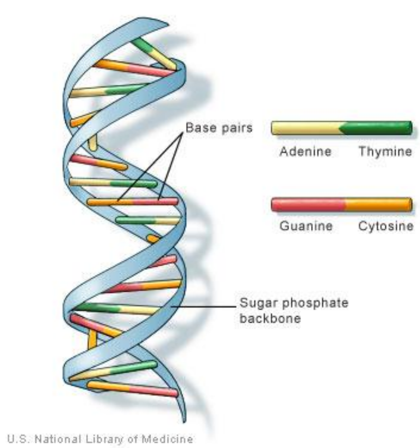

Figure-1: Diagram of the DNA Double Helical Structure. Shown are the double helical strands (blue) joined by base pairs (colored rungs of the ladder). (Freudenrich, 2007)

DNA is passed from parents to offspring giving some genetic qualities and characteristics of the parents. The visible form of DNA is the chromosome. Each human being has twenty three pairs of chromosomes. Forty six in total, with each parent donating half of the genetic material to each child. DNA is coiled tightly around proteins called histones, which combines with DNA to form chromosomes. These chromosomes are in the nucleus of every cell in the human body holding the genes that make each individual unique.

CODIS 13 Core Loci

The Federal Bureau of Investigation currently requires that entries into their database, the Combined DNA Index System (CODIS) include information from a set of thirteen loci or locations for their standard DNA test. These thirteen core loci were carefully chosen due to their uniqueness (there is almost a one in a billion chance that any two thirteen loci profiles will be the same between two people, excluding identical twins), and equally important the loci contain no medical information.

DNA Analysis Techniques

Several techniques have been developed to make the process of creating a DNA profile more reliable, each has its own advantages and disadvantages.

RFLPs, Southern Blots and VNTRs

The restriction fragment length polymorphism (RFLP) technique was one of the first techniques developed for doing DNA comparisons (Jeffreys et al., 1985a). This technique is based on an earlier Southern blot test (Southern, 1975), and takes advantage of the characteristics of restriction enzymes to cut DNA at specific locations (**Figure-2**). Once the DNA sample has been isolated from a tissue sample, a restriction enzyme is used to cut the DNA at specific sequence patterns along the double helix. The enzyme cuts the DNA into fragments. Then the fragments are separated by size using electrophoresis. The smaller the DNA fragment, the farther through the gel it migrates. The DNA fragment pattern is then blotted from the gel to a membrane, then hybridized to a DNA probe against the RFLP of interest. The probe is radiolabeled to allows its location to be determined by x-ray film (Davidson College, 2006), or it may be located by chemi-luminescence when exposed to enzymes that convert a chemical substrate to light.

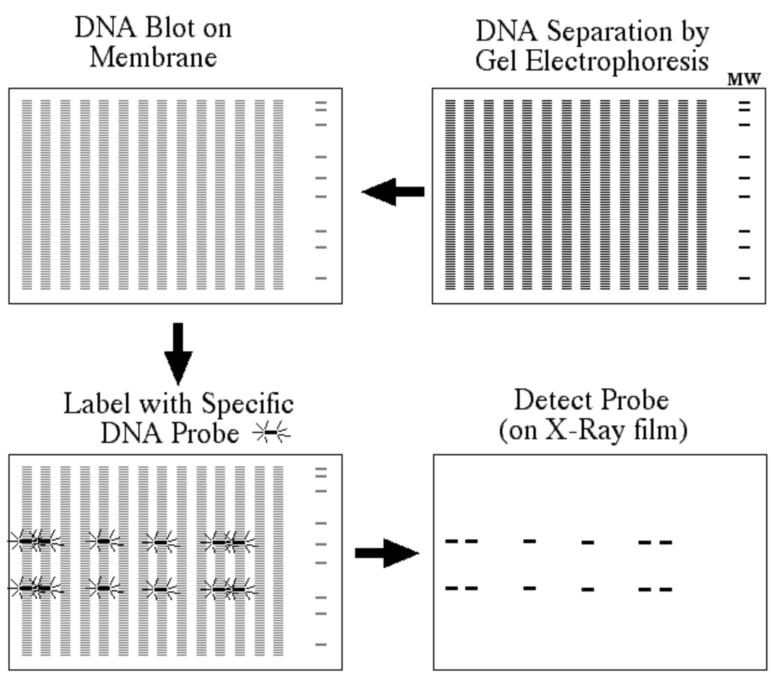

Figure-2: Diagram of the Southern Blot Process. (Southern Blot, 2009)

The resulting RFLP product is a visual pattern of specific RFLP fragments of interest (lower right panel in the figure), that represents a person's DNA fingerprint. This print can now be compared to other prints from known and unknown samples to help identify who was involved in a crime.

Variable numbers of tandem repeats (VNTR) refers to the fact that some sequences within DNA occur repeatedly. This repetitive DNA often varies considerably between individuals, so can be analyzed for identification purposes. VNTR sequences are analyzed by Southern blots, but in this case the different patterns result from different lengths of the fragments from a different number of repetitive sequences. The pattern can vary from four to forty times.

The Southern blot technique is fairly time consuming compared to other methods of DNA testing, and requires a relatively large DNA sample, so this technique is best used in paternity testing to discover connections between parents and offspring, when ample DNA is available. This technique is also very reliable and is not strongly affected by outside contaminates resulting in accurate and consistently correct results. The disadvantage is the method is non-amplifying so it requires a larger DNA sample.

PCR-STR DNA Analysis

VNTRs typically contain between nine and eighty base pairs, while short tandem repeats (STRs) contain between two and five base pairs. The STRs are so short, they can be amplified by polymerase chain reaction (PCR), providing us with an extremely sensitive technique that can be applied to very small DNA samples. With the use of PCR, a very small amount of DNA (even from one cell) can be "molecularly photocopied" many times to make the sample as large as needed to easily visualize differences. The PCR process uses a thermocycler to change the temperature of the PCR reaction (**Figure-3**). The DNA fragments are first heated to between ninety-four and ninety-six degrees Celsius to denature the DNA template to make single strands (step-1 in the figure). The fragments are then cooled to sixty-eight degrees Celsius to allow the sense and antisense DNA primers to anneal to the template in position flanking the STR region to be amplified (step-2). The mixture is then heated again slightly to seventy-two degrees Celsius to allow Taq DNA polymerase in the reaction to synthesize new DNA beginning at the primer sites (step-3) to create two new DNA double helixes. The process is then repeated between thirty and forty times to create millions of copies of the STR. The PCR process is completely automated thanks to the thermocycler, and more than one billion exact copies of the STR can be made in just a few hours (Rice, 2006).

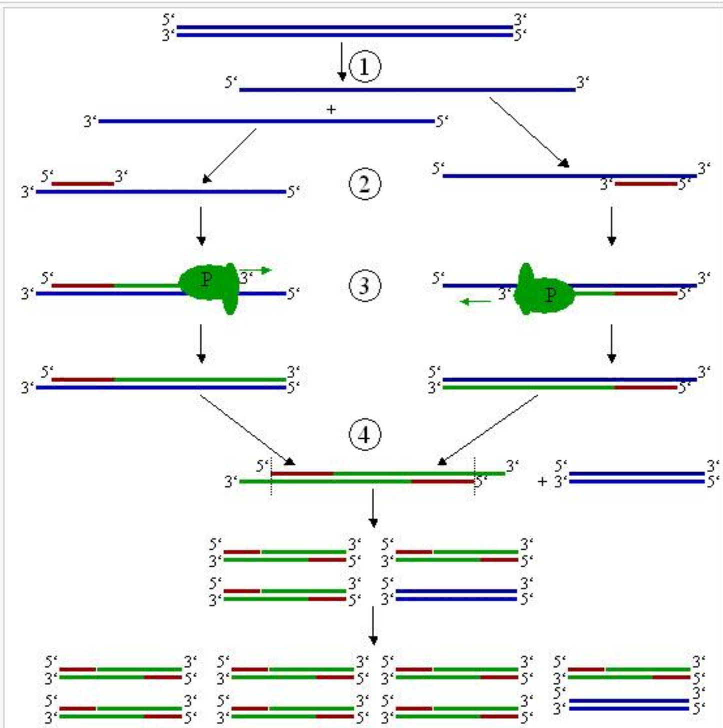

Figure 2: Schematic drawing of the PCR cycle. (1) Denaturing at 94-96°C. (2) Annealing at (eg) 68°C. (3) Elongation at 72°C (P=Polymerase). (4) The first cycle is complete. The two resulting DNA strands make up the template DNA for the next cycle, thus doubling the amount of DNA duplicated for each new cycle.

Figure-3: Diagram of the PCR Process.
(Rice, 2006)

Standard DNA analysis now includes 13 core STR loci. Each STR locus is specifically picked to be close to other surrounding loci but to not overlap with each other, allowing multiple STRs to be analyzed simultaneously in one PCR reaction (**Figure-4**).

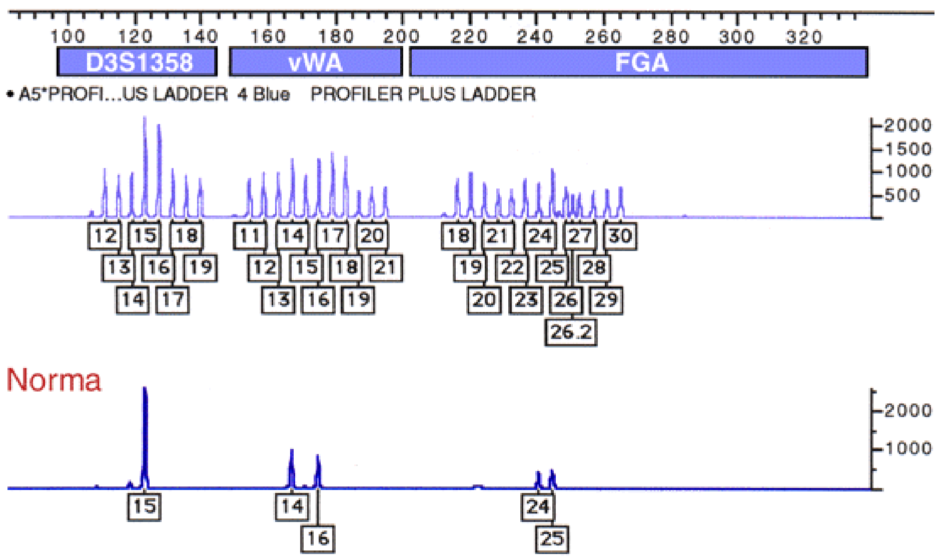

Figure-4: Analysis of Three Separate Non-Overlapping STRs. The diagram shows three loci, D3S1358, vWA, and FGA. (The Biology Project, 2000)

Due to its sensitivity and speed, PCR-STR testing has become the most common technique used today. This has the advantage of being able to start with a very small amount of DNA in an original sample. However, PCR is so sensitive it is prone to contamination. Contamination can be an issue if there is even the smallest amount of DNA present from another person, as it will be amplified along with the forensic sample.

DNA Applications

DNA has become a multifaceted tool to help solve crimes, paternity cases, identify human remains, track the illegal poaching of protected animal species, or help study human historical migrations. This has made DNA analysis to be a large commercial enterprise, with large companies dedicating huge amounts of resources to DNA analysis and maintaining DNA databases.

The first use of DNA testing for identification was paternity testing (Jeffreys et al., 1985b). This first case helped prove that a son was related to his British mother, allowing the son to stay in Britain instead of being deported. The most common use for DNA testing is taking the DNA of the mother and child, then comparing the profiles to potential fathers. With this technique, experts can determine who the father is, based on the close resemblance of the child's DNA profile to that of the father and mother (Health and DNA, 2006). This has become a much commercialized science, and has even been on daytime television with shows such as Jerry Springer using the science to determine the father of children with a live audience present for the results announcement. Paternity testing can also be used as evidence in criminal cases of sexual abuse of a minor that may result in pregnancy. The father can be identified from a group of suspects, leading to a high rate of conviction for these types of cases.

The second most frequent use for DNA testing is criminal forensics. DNA fingerprinting in court has slowly gained acceptance over the past few years, and has become a reliable means for identification of assailants in various crimes. **Figure-5** shows an example of the DNA analysis of a sexual assault case. Note in this example, the DNA profile of suspect-1 matches the profile of sperm taken from the victim. DNA fingerprinting has gained general acceptance in the scientific community, and has allowed the conviction of criminals even based solely upon the DNA profiling evidence.

Figure-5: Visual Comparison of DNA Samples from a Sexual Assault Case. (Freudenrich, 2007)

Molecular archeology is another form of DNA analysis that is similar to paternity testing but it traces and connects people or animal species across time, making ancestral connections based on the similarity of the profiles. One of the most amazing finds in archaeology was "Tyrolean Ice-Man" a mummy found in the Italian Alps. Based on an analysis of his clothing, he was determined to be about five thousand three hundred and fifty years old. DNA taken from his preserved stomach cells indicated he originated in Northern Italy. The dry cold climate helped keep the mummy completely preserved (Ermini et al., 2008).

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Chapter-2: DNA Forensics

Jessica White

"DNA does more than just help identify an individual; it can place a known individual at a crime scene, in a home, or in a room where the suspect claims to not have been. It can refute a claim of self-defense or put a weapon in the suspect's hand. It can change a story from an alibi to one of consent. The more officers learn how to use DNA, the more powerful a tool it becomes." (What Every Law Enforcement Officer Should Know, 1999). The collection of DNA evidence at a crime scene can be crucial to solving a case; however even with this powerful technology, any small mistake can make the evidence inadmissible in court. The purpose of this chapter is to discuss recent advances in the proper collection, handling, and storage of DNA evidence that help allow its acceptance in the court room.

The first step to getting DNA evidence accepted in a court room is to control and organize the crime scene. Then it is important to collect and store the DNA evidence without contaminating or degrading it. A proper chain of custody shows who handled the evidence and why. Finally, the DNA analysis itself must be carefully performed with proper controls.

Crime Scene Procedures

Having an organized and consistent way of processing a crime scene can increase the validity of the evidence brought to court. There are three stages typically enforced while processing a crime scene: scene recognition, scene documentation, and evidence collection (Byrd, 2000). The scene recognition stage is the first initial organized and legal search or walkthrough of the crime scene. During this time, a search pattern is determined based on the number of searchers, the size of the area, the terrain, etc. Next, a plan of operation is constructed that lays out where evidence might reside, how quickly it needs to be collected, and what resources are needed to process it. Then the scene is documented, depicting every detail of the area. The information documented during this stage will allow for later reconstruction of the crime scene in court. Then the evidence is collected, which must be performed very carefully; it is a very delicate and time consuming process. More details regarding this process will be discussed later in the chapter. (Byrd, 2000)

Every person that responds to a crime scene plays a specific role in the investigation. Police officers usually are the first to arrive at the scene; they make an arrest if possible, and call an ambulance if needed. They are also responsible for securing the three levels of containment (discussed below) to ensure that no evidence is destroyed. The CSI unit documents the scene in detail and collects any physical evidence that is found. The district attorney is present at a crime scene to determine if the investigators require a search warrant to continue their examination. The medical examiner, if a death has occurred, may be present to determine a cause of death. Specialists will sometimes be used to investigate the scene; these people consist of entomologists, forensic scientists, forensic psychologists, etc. Detectives arrive at the scene to interview witnesses and consult with CSI; they investigate by following leads provided by witnesses and evidence. (Layton, 2004)

There are three basic levels of containment surrounding a crime scene: primary containment, secondary containment, and perimeter containment (**Figure-1**). The primary containment is the most basic; it consists of the area directly surrounding the crime scene. The responding officers usually determine and tape off this area, with the possibility of slight modifications once the initial confusion cools down. This tape surrounds all of the places where evidence may be, including areas of entrance and egress, with some extra space for insurance.

The secondary containment level surrounds the entirety of the first level, ensuring that it is protected from any outside individuals. This area can be used for storage of crime scene vehicles, makeshift desks, and break areas for crime scene workers to avoid signing in and out. The third and final level of containment is the perimeter; this level of containment is created around the secondary level with police vehicles and barricades. The primary purpose of this level is to keep any unauthorized vehicles or foot traffic away from the crime scene. (Dagnam, 2006)

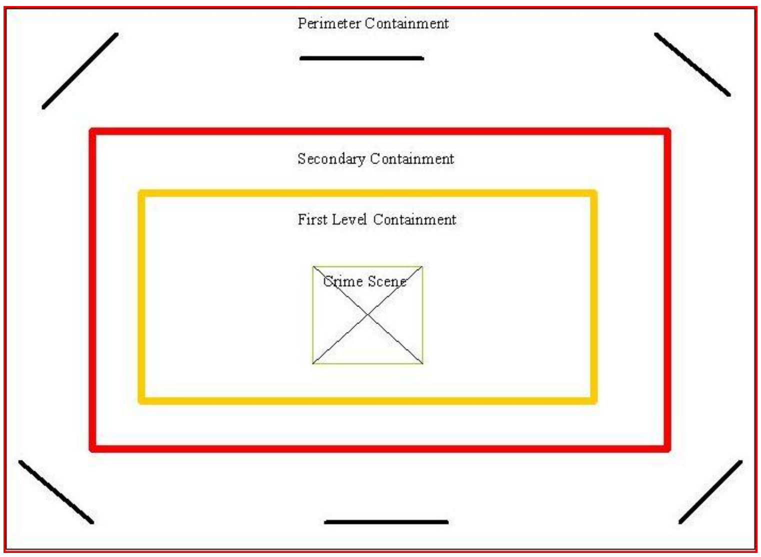


Figure-1: Diagram of the Three Containment Levels Surrounding a Crime Scene. This figure shows the relative position of primary, secondary, and perimeter levels of containment relative to the original crime scene. (Dagnam, 2006).

The pattern of containment laid out during the initial scene recognition stage will include a walking path for investigators. The goal of this pre-determined path is to have people walk in an area that is the least likely to contain evidence that could be destroyed. There are several patterns to choose from to ensure that there is full coverage of the crime scene, and that the resources are used the most efficiently (**Figure-2**). The inward spiral search (diagram upper left panel) is where the investigator starts at the perimeter of the scene and circles through the room toward the center. This is often a good method when there is only one CSI present. The outward spiral search (diagram upper middle panel) is basically the same except you move from the middle of the room to the perimeter. The parallel search (diagram upper right) is where every member of the CSI team walks in a straight line, at the same speed, from one end of the scene to the other. The grid search pattern (lower left panel) is basically two parallel searches 90 degrees from one another, performed consecutively. In the zone search (lower right panel) the lead CSI divides the room into sections, and each member of the team takes one sector. They may decide to switch sectors, after the search is complete and conduct it again to ensure full coverage of the crime scene. (Layton, 2004)

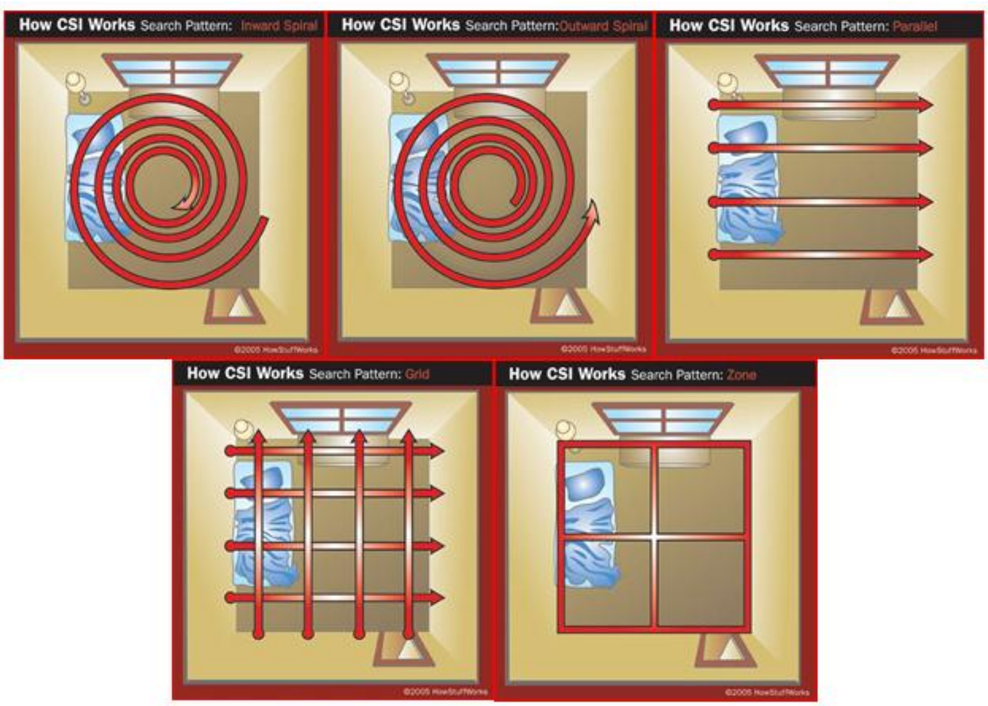


Figure-2: Five Typical Search Patterns that CSI's use in Investigating a Crime Scene. Shown from upper left to lower right are the inward spiral search, outward spiral search, parallel search, grid pattern search, and zone search. (Layton, 2004)

There are three basic steps to documenting a crime scene properly: written notes and reports, photographs, and sketches. The notes and reports should be completed in chronological order, and should include only the facts of the case, leaving out opinions and conclusions. The photographs taken at the scene should depict the scene as it is observed before any evidence is handled or moved. Later these photos will act as a visual record of the crime scene and the items of collected evidence. Usually three views are portrayed in the photos: the overall scene, showing as much of the area as possible; the mid-range, showing the relationships of items; and the close up of each piece of evidence. These photographs should be taken with tags identifying the evidence depicted, along with a second photo (if necessary for analysis) with a measuring device to show where the evidence is located. Sketches are taken to accurately show the appearance of a crime scene, mostly to show the position of items in relationship to one another. The main advantage of a sketch is that it can be drawn to leave out areas of clutter shown in photographs. (Byrd, 2000)

DNA Evidence

DNA evidence can be very valuable to solving a case, as it places the suspect at the scene of the crime. The goal of gathering evidence is to, "collect and preserve all physical evidence that might serve to recreate the crime and identify the perpetrator in a manner that will stand up in court" (Layton, 2004). Sometimes evidence can be present in areas that are unexpected, so a crime scene investigator must be trained to recognize the places where DNA might be located (**Figure-3**). Blood evidence, due to its high DNA content, is extremely helpful in the presentation of a case, as it can contain a large quantity of DNA in the nucleated white blood cells. Semen also contains a large amount of DNA in the nucleated sperm cells. Physical evidence can come in many different forms including: trace evidence, gunshot residue, broken glass, drugs, impressions, fingerprints, footwear, tool marks, hair, fibers; weapons, knives, guns, cartridge casings, diaries, suicide notes, phone books, etc. The crime scene investigator will first examine the body, if it is a homicide, then will continue searching the surrounding area as described in the crime scene procedures section above. Before the body is moved in any way, they must look for stains or marks on the clothing, determine if the clothing indicates dragging, bruises, cuts, or marks on the body, determine if there are large amounts of blood in any particular pattern or other bodily fluids, and determine if there is insect activity around the body. While searching the crime scene, the focus is on whether the doors and windows are open or locked, do they show any signs of forced entry, is the house in order or was there a sign of a struggle, is there any signs of a party, do the ashtrays contain cigarettes, is there anything out of place such as the toilet seat being up in a woman's apartment, are there tire marks in the driveway or around the building, is there any blood spatter, etc.

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

Type of Sample[1]	DNA Content[1]	PCR Success Rate[1]
Liquid Blood	20000-40000 ng/mL	>95%
Blood Stain (1 cm x 1cm)	200 ng	
Liquid Semen	150000-300000 ng/mL	>95%
Post-coital Vaginal Swab	0-3000 ng	
Liquid Saliva	1000-10000 ng/mL	50-70%
Plucked Hair (with root)	1-750 ng	>90%
Shed Hair (with root)	1-12 ng	<20%
Urine	1-20 ng/mL	

Figure-3: DNA Evidence. Left Table, List of Where DNA Evidence Might be Located at a Crime Scene (What Every Law Enforcement Officer Should Know, 1999). Right Table, List of How Much DNA is Present in a Biological Sample (Kayne and Sensabaugh, 2000)

In cases where the suspect has tried to clean up evidence, it may be hard to find blood on surfaces. In fact, blood can go unnoticed on a most surfaces for years. Since “much of crime scene investigation, is based on the notion that nothing vanishes without a trace,” products such as luminol, have been developed to uncover this hidden evidence (Harris, 1998). The purpose of luminol is to reveal traces of blood residue at a crime scene using a light-producing chemical reaction that occurs between certain chemicals and hemoglobin (**Figure-4**). The process applied here, generally known as chemiluminescence, happens when the reactants have more energy than the final products, causing the molecules to get rid of the extra energy as light photons. Luminol is a powdery substance made up of nitrogen, hydrogen, oxygen, and carbon. This compound is then mixed with a liquid comprised of hydrogen peroxide, hydroxide, and other chemicals. If blood is present, the iron in the hemoglobin acts as a catalyst for the reaction between luminol and the hydrogen peroxide giving off light (Harris, 1998).

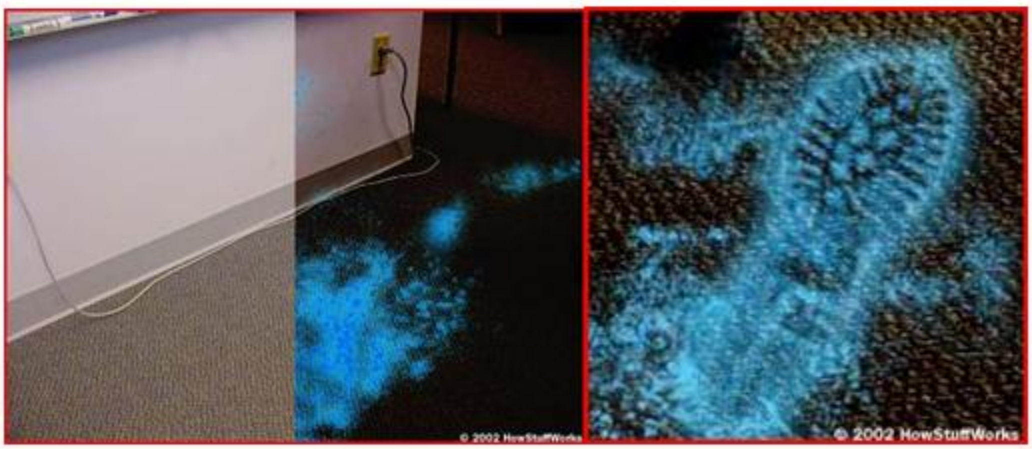


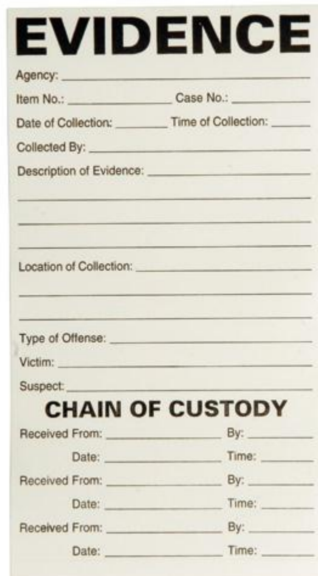
Figure-4: A Simulation of Luminol at Work. (Layton, 2004)

Once the luminol reveals apparent blood traces, investigators can photograph the area affected to record any patterns that appear. However, blood is not the only substance that can react with the luminol, in fact common products such as household bleach can also cause the reaction. Well trained investigators make a reliable identification based on the speed in which the reaction occurs, but further testing is required to verify that the area is in fact covered with blood. Luminol usually does not act as a case closer, most of the time it just gives investigators a lead on blood spatter patterns consistent with certain weapons or where an attack happened. In some cases, luminol can lead investigators to more evidence; for example if blood is revealed on top of a carpet, they can pull it up to find visible blood stains on the floor boards below. The main disadvantage to using luminol is that the chemical reaction can destroy other evidence, including DNA, so extra blood needs to be identified if possible for isolating the DNA. Usually luminol is used after all other options are exhausted to gain a new lead (Harris, 1998).

Luminol is not the only technique that can be used to find evidence that cannot be seen. Some bodily fluids such as semen, vaginal fluid, and saliva will directly be luminescent under a black light or UV lighting. This is a common method used in the investigation because it does not damage the evidence, and it can narrow down the location of evidence rather quickly. The use of a powerful white light on a carpet can make hair and fiber evidence more noticeable. Some hair if it has been bleached, dyed, or very lightly colored will also glow under UV lighting (Horiba Scientific, 2011).

Chain of Custody

Whenever a piece of evidence is handled, there is a question of whether it could have been contaminated by that individual. By documenting each time a sample was handled, by whom, and what was done with it at the time, this question can be answered. A chain of custody form (**Figure-5**) must be filled out for each piece of evidence, from the time it is collected through all the way to the courtroom. The form travels with the sample wherever it goes, and a second copy is usually kept on file in the case folder. The information included on the chain of custody includes: sample initial location, description, the type of container it is stored in, whether it was sealed, the case number, and who handled it (Schiro, 2001). These forms protect the integrity of the evidence in court, without this documentation the origin of the evidence can be questioned (Layton, 2004). Recording a chain of custody can ensure that the evidence meets the legal and scientific requirements for admissibility in a court of law (Handbook of Forensic Services, 2007)


EVIDENCE

Agency: ____________

Item No.: ______ Case No.: ______

Date of Collection: ______ Time of Collection: ______

Collected By: ____________

Description of Evidence: ____________

Location of Collection: ____________

Type of Offense: ____________

Victim: ____________

Suspect: ____________

CHAIN OF CUSTODY

Received From: ______ By: ______

Date: ______ Time: ______

Received From: ______ By: ______

Date: ______ Time: ______

Received From: ______ By: ______

Date: ______ Time: ______

Figure-5: Example of Evidence Label that Includes the Chain of Custody Information. (Arrowhead Forensics, Inc., 2007)

DNA Contamination

Contamination of DNA evidence is a large concern when working on a case; if the evidence is found to be contaminated in any way, it may no longer be admissible in court. The suspect could walk away free if there is no other evidence to holding them responsible for the crime. Sometimes, DNA evidence can be microscopic since only a few cells are necessary to extract a DNA sample, so great precautions must be taken while handling a sample during the identification, collection, and preservation of evidence to ensure the collector's DNA does not contaminate the evidence. A DNA specimen can be considered contaminated if DNA from any other source blends with the evidence DNA. A new technology has been formed known as "PCR" (Polymerase Chain Reaction) which amplifies the DNA contained in a sample, thus making contamination even more of an issue; the PCR process will duplicate whatever sample is present exactly. There is no way for PCR to differentiate between the suspect's DNA from another source (What Every Law Enforcement Officer Should Know, 1999).

There are specific precautions a person working with the DNA sample can take to avoid contamination, including wearing gloves and changing them often, using disposable instruments or cleaning them thoroughly between interactions with samples, avoiding touching areas where DNA may exist, refraining from talking, sneezing, or coughing around the evidence, avoiding touching your face, nose, or mouth when collecting or packaging evidence, air-drying the evidence thoroughly before packaging, storing evidence in paper bags or envelopes, not plastic bags, this will help prevent moisture buildup and DNA degradation, and not using staples, which can easily prick investigators fingers causing their blood to contaminate the evidence (What Every Law Enforcement Officer Should Know, 1999). Any pieces of evidence that could contaminate one another should be stored separately. Investigators should ensure that all containers are closed tightly to prevent the blending of material in the transportation process. Each piece of evidence should be properly labeled with the date, time, location, and person who collected it. Lastly, the investigator should consider the conditions under which the sample should be stored; for example blood should not be exposed to heat or humidity, making it crucial that it is refrigerated whenever possible (Schiro, 2001).

Evidence Collection and Packaging

The collection and storage of evidence is a very delicate and time consuming process. If it is not done correctly, the evidence may be contaminated and may not be admissible in court. Each type of evidence has specific techniques that are usually used in its collection. Evidence comes in many forms including: trace evidence, bodily fluids, hair, fibers, fingerprints, footwear impressions, tool marks, and firearms (Layton, 2004). Trace evidence can include gun-shot residue (GSR), paint residue, chemicals, glass, or illegal drugs. During the process of collecting the evidence, the CSI will wear gloves, booties, face mask, and gown to protect themselves and the evidence being collected. They might use tweezers, vacuums with filters, or a knife to collect the evidence storing it in plastic containers with lids (**Figure-6**). If there is a gun involved in the crime, CSI might collect clothing from the victim and anyone else on the scene for GSR testing. If there is gun-shot residue on the victim, he could have been shot from close range; if it is found on anyone else they may be a suspect. If any illicit drugs are found on the scene, they are usually sealed in a separate, sterile, storage container. Trace items can be found in bedding, clothing, towels, or couch cushions. Some labs will take these items to a sterile room with white floors to shake them for evidence (Layton, 2004).

Figure-6: Examples of Evidence Collection Tools and Storage Containers. Left: Gun-shot Residue Collection Kit; Middle: Cuticle Sticks; Right: Storage Containers with Lids. (Arrowhead Forensics, Inc., 1998).

Body fluids might include blood, semen, saliva, or vomit. When collecting these fluids, the same protective gear should be worn in the collection process as for trace evidence, with the addition of protective eyewear. To collect this type of evidence, a CSI might use smear slides, a scalpel, tweezers, or sterile cloth squares. The detection of these items is laid out in the DNA evidence section of this chapter. Samples must be collected from the victim and any suspects and returned to the lab for comparison. The victim's nails might be scraped with a cuticle stick, for skin in case there was a struggle. In addition to collecting the samples of blood, a CSI must study and document the blood spatter patterns. These patterns can reveal what type of weapon was used, the location of the attack, and even the direction of the attack (Layton, 2004).

Traditional fingerprints may be taken from the scene to help in identifying the victim and suspect, or to rule out a suspect. Many types of tools can be used during the collection of fingerprints including: brushes, powders, tape, chemicals, lift cards, a magnifying glass, or super glue (**Figure-7**). There are three types of prints a CSI might find: visible, left by the transfer of fluid, can be viewed by the naked eye; molded, left in a soft soap, putty, or candle wax, these show up as impressions in the material; or latent left by the transfer of sweat and oils, not visible to the naked eye. The powder used comes in metallic silver or velvet black, designed to contrast with the flat surface a print is on. The CSI brushes the powder on until a print is visible, takes a picture to document the location, and then uses the lift tape to collect it. Chemicals such as iodine, ninhydrin, or silver nitrate can be used on porous surfaces for print collection. Finally, cyanoacrylate (super glue) can be used for non-porous surfaces to collect latent prints with the assistance of heat and an airtight container (Layton, 2004).

Figure-7: Examples of DNA Collection Kits. Left: Powders and brushes used to collect traditional fingerprints. Right: Footprint impression mold. (Layton, 2004; Arrowhead Forensics, Inc., 1998)

Footwear impressions and tool marks can give the investigators clues about the suspect and/or the murder weapon. If it is not possible to take the entire object that contains the footprint, the CSI will make a casting at the scene. A casting kit may include: casting compounds, dental gypsum, silicone rubber, snow wax for making a casting in snow, a bowl, or a spatula. A cast is much harder to construct for tool mark impressions, but if it is not possible to take the whole object, then one is made just in case. There are two types of tool marks: impressed, where a hard object contacts a softer one with no side to side motion, and striated, where a hard object contacts a softer one and moves back and forth leaving parallel lines that are easier to identify (Layton, 2004).

In the case of firearms, bullets, or casings at the crime scene, the CSI will pick the gun up by the barrel and bag everything separately for transportation to the lab. At the lab, forensic scientists can trace bullets back not only to the guns that they were fired from, but to previous cases through ballistics databases. The direction of the shot, position of the victim, and where the shot was fired from can all be determined using a laser trajectory kit. If a bullet is embedded in the wall, that portion of the wall is cut out and sent to the lab for analysis. It is important not to damage the bullet any further by digging it out at the scene (Layton, 2004).

Chapter-2 Conclusion

The main goal of a Crime Scene Investigator (CSI) and forensic scientists is to protect evidence collected at a crime scene from contamination so that a DNA sample can be extracted from it with confidence and used in court. These individuals work hard to record very thorough chain of custody reports that are strong enough to hold up in court, and use collection procedures that prevent contamination from any evidence handler or from other crime scene evidence. Through the use of organized and consistent crime scene procedures and well documented reports, CSI's can help assure a DNA sample's acceptance.

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Chapter-3: Landmark DNA Court Cases

Cody McCormick

The development of DNA as a science and a tool in the courtroom did not occur overnight. As the science developed and became more reliable and accepted in the scientific community, DNA profiling gradually gained acceptance in the courtroom and developed into a great forensic tool. The acceptance of any new technique or type of evidence in courts requires original debate and court decisions. Only rarely does a court case culminate in an original decision. Most court cases base their final outcome on previously decided cases which deal with situations of similar controversy. The few landmark court cases that have made original decisions on new subjects are frequently referenced whenever the issue arises in future cases. The purpose of this chapter is to discuss several key landmark court cases that set precedence for allowing DNA evidence in US courts.

Frye v. United States (1923)

On November 25, 1920 a wealthy physician named Robert W. Brown was killed in his office in Washington D.C. A fellow physician witnessing the crime chased after the murderer but the chase was short lived because the suspect began firing upon the witness (Fisher, 2008). The witness did not know the man he was chasing, so the police were unable to arrest anyone for the murder. Seven months later on August 21, 1921 James Frye was arrested for an armed robbery he had committed, and confessed to both the armed robbery and the earlier murder of Doctor Brown (Fisher, 2008). He later retracted his confession and the case went to trial (*Frye v US*, 1923).

A few weeks before the trial, William Marston was called in to perform a then new "lie detector test" on Frye regarding the retraction of his confession. Through the use of his "systolic blood pressure test" he was convinced of Frye's innocence. This was a great shock to many familiar with the case. Judge William McCoy presided over the hearings which only lasted four days. Frye's defense was based upon his alibi and the results of Marston's lie detector test. Due to the unproven and unreliable methods which Marston used, taking Frye's blood pressure with an arm cuff after he answered a question, Judge McCoy did not allow the results to be used as evidence (Fisher, 2008). The trial lasted four days and concluded with a guilty verdict for second degree murder, and a sentence of life in prison. The lie detector test most likely saved his life, since a conviction of first degree murder would have resulted in the death penalty. The sentence was most likely lessoned due to the debate over the admittance of Marston's test results and the fact that the test took place in front of the jury. The jury could not help but lesson the punishment considering anyone hearing that a form of lie detector test proved a man was innocent of a crime. This juror influence is what Judge McCoy hoped would not occur.

In 1923, the case was appealed, but to no avail the verdict handed down by Judge McCoy was upheld by the second judge, and the lie detector results were still not allowed as evidence (Fisher, 2008). Both judges decided that the lie detector test via the systolic blood pressure method was not *generally accepted* in the scientific community, so it was dismissed from the courtroom.

This case established the now famous *Frye Standard* that new technology had to be *generally accepted* in the scientific community before it would be allowed in the courtroom as evidence. This set the science of lie detection back almost sixty years before it was considered for the courtroom again (Fisher, 2008), and to this date many courts do not allow this as conclusive evidence because the results can be influenced by the person being examined. The precedent set by this case would be referred to for a long time until *Federal Rules of Evidence Rule 702* was established in 1975 to replace it with an easier to achieve reliability standard. The Frye case set the first standard for allowing complex scientific evidence. If a technique was not accepted by the scientific community, then the courtroom would not allow it as evidence. The lie detector had failed this test but DNA had not yet challenged the standard but would much later in *Two Bulls* in 1990.

United States v Downing, 1985

John W. Downing was convicted in Pennsylvania of mail fraud, wire fraud, and interstate transportation of stolen property. The defendant supposedly defrauded many manufacturers through a group called the Universal League of Clergy (ULC). This group provided fake credit references along with other falsified credentials. The ULC would have products shipped to them on credit, and then sell the products without ever paying the manufacturers. This organization was run by several figure heads, the main person was a “Reverend Claymore” who was the main defendant in *United States v John W. Downing*, 1985. In this trial, twelve eye witnesses were the basis for Downing being identified as Reverend Claymore. Their personal contact with Downing ranged between five and forty-five minutes of contact for normal business transactions. The co-defendants, James A. Silva and Richard Piazza, admitted to establishing the ULC, but denied any knowledge of the defrauding of the companies and claimed to have been set up. They also asserted that Downing was wrongfully identified as Reverend Claymore, and if the true Reverend Claymore could be found their innocence would be proven.

To assist in the defense, Robert Weisburg, PhD, of Temple University a cognitive psychologist was called to be an expert witness in the subject of human memory (*United States v John Downing*, 1985). The defense wanted him to testify about the unreliable nature of eyewitness testimony and to help discredit the eyewitness accounts. But the judge did not allow him to testify on the grounds that it was the jury's duty to give credibility to a witness. The judge believed the expert would override the jury's purpose in the trial. Without the expert testimony, the case went to trial and the jury convicted Downing of all charges. Downing later appealed the court decision based on the expert testimony being thrown out, but the guilty verdict was upheld.

The Downing case set a precedent that the judge has the right to throw out any evidence deemed misleading or detrimental to the jury's decision. Based on the earlier *reliability* and *relevance Rule 702*, it was concluded by the district court that "expert testimony concerning the reliability of eyewitness identifications is never admissible in federal court because such testimony concerns a matter of common experience that the jury is itself presumed to possess" (*United States v John Downing*, 1985). This appellate court decision effectively eliminated the ability to have expert testimony on the reliability of eyewitnesses because the expert would never meet the standards of relevancy set forth by Rule 702. This precedence allows the judge to dismiss any misleading or detrimental testimonies or evidence used to divert the court proceedings.

Colin Pitchfork, 1983-1988

On November 22, 1983 the murder of a fifteen year old girl, Lynda Mann, shocked the small U.K. town of Narborough (Batt, 1999). Her body was discovered on a shady walking path brutally raped and strangled. An extensive search was conducted, but police could find no leads as to the identity of the murder except for a small semen sample. The case went unsolved until another fifteen year old girl, Dawn Ashford, was also found raped and strangled on July 31, 1987 (Batt, 1999). The similarities between the two cases were too close to be ignored, and the police concluded that the same murderer had committed both crimes. A search was conducted again, but no suspects panned out.

A break in the case came when police were tipped off about a seventeen year old man named Richard John Buckland. He initially refused to admit any association with either crime, but after a lengthy questioning process he confessed to the murder of Dawn, but refused to admit to the murder of Lynda. One of the police officers had recently read an article about a new scientific technique for DNA fingerprinting, invented in 1984 by Professor Alec Jeffreys of Leicester University (Jeffreys et al., 1985a). It had been previously used to solve a paternity case (Jeffreys et al., 1985b), but had not yet been used to solve a crime. The police figured it might be used to match Buckland's DNA to the crime evidence. Everyone was shocked when the DNA results affirmed his innocence, so the investigator had to start from square one. Buckland became the first person exonerated of a crime by DNA evidence.

A new attack plan was formed, and the investigators collected blood samples from every male between the ages of thirteen and thirty living in three local villages. Samples from over five thousand people were analyzed, but produced no matches. With the extreme amounts of attention the case was receiving, a major breakthrough finally occurred when a woman owning a local bakery overheard a man bragging that he paid his friend to give a blood sample in his place. The man avoiding the DNA test was Colin Pitchfork, who was soon arrested and confessed to the crimes with the knowledge that the DNA test would result in a match, which it did (Batt, 1999).

Colin Pitchfork was sentenced to life in prison on January 22, 1988. On May 14, 2009, Pitchfork appealed his case on the grounds that he had used his twenty years in prison to gain a very specific knowledge of converting sheet music to brail. With this in consideration his sentence was lessened by two years, so instead of the minimum thirty years in prison he is eligible for parole in 2016 (Kennedy, 2009).

The precedent established by the Pitchfork case is the conclusive nature of DNA fingerprinting and its acceptance in court. Colin Pitchfork was the first person ever convicted of a crime with the aid of DNA evidence (Batt, 1999). Richard Buckland was the first man ever proved innocent through DNA evidence (Batt, 1999). With this case the possibilities of using DNA in the courtroom were first founded. DNA had now become a viable science which was reliable enough and trusted in the scientific community to weigh on the verdict of court cases and deciding people's fate in the legal system.

Andrews v State of Florida, 1988

On the morning of February 21, 1987 Tommie Lee Andrews invaded the home of his victim and then raped her while she was still in bed, holding a razor to her throat while covering her mouth with his hand. He proceeded to threaten her life if she saw his face and when she struggled against him he cut her face, neck, legs, and feet. He then stole her purse containing forty dollars. Andrews was charged with aggravated battery, sexual battery, and armed burglary of the dwelling. The evidence against him was both DNA from a semen sample found in the victim when she was examined shortly after the attack, and traditional fingerprints found at the point of entry to the home. Both Andrews and his victim were blood type O, leading to a possibly contaminated sample of semen taken from the victim that contained her own blood

(*Andrews v. State of Florida, 1988)*. This similar type O match between victim and suspect would not be a problem with a more complete forensic DNA analysis. The forensic DNA test performed compared the DNA from Andrews's blood to both the DNA of the blood and semen samples collected from the victim. LifeCodes Corporation, who specializes in DNA identity testing, was responsible for the testing performed for this case. Dr. Baird from the Life codes Corporation testified on their behalf that the results of the test were incredibly conclusive, matching Andrew's blood sample to that of the semen with only a one in eight hundred million chance that another person in the population would have the same match. The DNA match led to Andrews' conviction.

Andrews appealed the conviction claiming the DNA evidence should not be allowed, and claiming his fingerprints could be explained in an innocent manner at the home. The defense attacked the methods by which Life codes Corporation conducted its tests and comparisons of the DNA evidence. Through in-depth interrogations and investigations, all of the LifeCodes steps methods and procedures were found to be acceptable, and the tests were determined to have been performed correctly. Dr. Baird of LifeCodes, who the defense attempted to discredit, was deemed an acceptable expert witness from his extensive background in the field of microbiology and one hundred and twenty papers published in the field of DNA. After failing to show fault or error in the DNA process, and failing to provide an innocent reason for his fingerprints being at the scene, Andrew's conviction was upheld (*Andrews v. State of Florida, 1988)*.

The precedent set by this case allowed DNA to be used in the US as a form of evidence, and affirmed its wide acceptance as a science. Through the relevancy test established by United States v Downing (1985) and the relevancy and reliability tests established by Rule 702, and the extensive literary citations of DNA evidence, this new technology gained a foothold in the US courts, providing police with a much needed new forensic test.

United States v Two Bulls, 1990

Mathew Sylvester Two Bulls was charged with aggravated sexual assault and sexual abuse of a minor after he raped a fourteen year old girl on Pine Ridge Indian Reservation in South Dakota. A semen sample was isolated on the girl's underwear by the Federal Bureau of Investigation and analyzed using DNA profiling. After also testing Two Bulls blood, it was concluded that there was a very high chance that he was guilty of the crime. Before the trial, Two Bulls made a motion to dismiss the DNA evidence. But after hearing the first witness, the judge ruled to allow the DNA evidence in court (*United States v. Matthew Sylvester Two Bulls, 1990)*. Two Bulls' defense argued that the court was incorrect to use the reliability Rule 702 as the standard for admission for the DNA evidence, and instead should use a stricter standard like the Frye general acceptance standard. Two Bulls established a new 5-prong standard to eliminate the lengthy pre-trial evaluations of admissibility of DNA evidence. Due to the high impact that DNA evidence can provide when convincing the jury of a decision one way or the other, it was concluded that to determine the admissibility of the DNA in a pre-trial hearing, a standard much more stringent than any used previously had to be used to ensure that if any error was made in the procedures the DNA would not be allowed, so the jury would not be unduly swayed. The court combined several previous standards to establish a new 5-prong standard to supersede all previous standards:

1) Whether DNA evidence is *generally accepted* by the scientific community (Frye Standard).
2) Whether testing procedures used in this case are generally accepted as *reliable* if performed properly (Rule 702).

3) Whether the test was performed properly in this case (Castro Standard).
4) Whether evidence is more prejudicial than probative in this case (Rule 702 and Downing Standard).
5) Whether the statistics used to determine the probability of someone else having the same genetic characteristics is more probative than prejudicial under Rule 403 (Downing Standard and Rule 403).

With this new more stringent standard established, the Two Bulls evidence was reviewed and it passed, thus it was allowed in court and the previous guilty verdict was upheld (*United States v. Matthew Sylvester Two Bulls, 1990)*. The 5-prong Two Bulls standard combines all the previous methods of admitting complex evidence into court cases. This cemented the ability of investigators and law enforcement to use DNA samples properly collected at crime scenes to be used in convicting criminals or exonerating the innocent. In this case, DNA profiling withstood serious scrutiny, and so long as proper procedures were followed and evidence is not rules as prejudicial, the evidence will be allowed.

People v Paul Eugene Robinson, 2000

In the early morning hours of August 25, 1994, Deborah L. was awoken to an unknown assailant in her bedroom holding a kitchen knife and wearing gardening gloves. He proceeded to climb on top of her and hold her at knife point while he sexually assaulted her. He proceeded to redress himself and leave the premises. Shortly after, the victim called the police and was sent to a medical facility where a rape kit was prepared. A vaginal swab was taken, which tested positive for semen. On August 21, 2000, four days before the six year expiration date of the statute of limitations ran out on the 1994 crime, a DNA profile was created from the sperm sample, and was used to create a “John Doe” warrant with the DNA profile attached. Normally, a warrant contains the name of the individual, his last known address, and the crime he is suspected of committing, but this warrant described a “John Doe, Unknown Male” with a thirteen locus point DNA profile describing the suspect. The document was prepared and signed by Magistrate Jane Ure on August 22, 2000.

This DNA profile of an unknown assailant was compared to the Convicted Offender Database of DNA samples, collected and maintained by the California Department of Justice. Soon after, a “cold hit” was established with a match between the sample taken from Deborah L. and a previously collected sample from Paul Eugene Robinson. After this information was sent to the investigators in charge of the case, on September 15, 2000, a second DNA profile was analyzed on a blood sample from Robinson himself and compared to the sample collected from Deborah. This confirmed with certainty a thirteen locus point match between the swab taken from the rape case and the profile of Robinson. The detective in charge then ran a background check on Robinson to discover he was no longer in custody and was out on parole with several other arrest warrants in his name. The John Doe DNA warrant was then amended to have his name, and Paul Eugene Robinson was arrested on September 15, 2000. He was convicted by a jury for one count of forcible oral copulation, two counts penetration with a foreign object, and two counts of rape (*People v. Paul Eugene Robinson*, 2000).

Robinson appealed the guilty verdict on the grounds that the “John Doe” warrant containing only a DNA profile should not have been granted, the statute of limitations on the crime had passed, his right to due process had been violated using a “John Doe” arrest warrant to surpass the statute of limitations on the crime, and the blood sample used to build the DNA profile was taken involuntarily. The “John Doe” warrant appeal was revoked after it was established that a thirteen point locus DNA profile cannot be disputed, and is as close to an infallible measure of identity as science can presently obtain (*People v. Paul Eugene Robinson,* 2000). The subsequent legitimate warrant then allowed for the arrest of the suspect Paul Robinson, and the taking of his blood for analysis. The appellate court ruled that an arrest warrant only requires a sufficient means for identification, so a 13 point DNA profile can serve that purpose, and Robinson's blood sample was found to have been taken correctly. So the appellate court found no substantial grounds for an appeal, and upheld Robinson's earlier conviction. This case resulted in a new precedent for the acceptance of DNA evidence in the court room, and was the first case to ever result in a conviction using only the DNA profile from a rape kit swab six years after the crime was committed. This was another affirmative precedence allowing further acceptance of DNA as substantial evidence beyond a reasonable doubt.

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Chapter-4: Sensational DNA Court Cases

Jessica White

The previous chapters described the various ways that DNA fingerprints are processed, the procedures of how to properly handle DNA evidence at a crime scene, and some landmark court cases that set the guidelines for the acceptance of DNA in a courtroom. But landmark DNA cases are often not familiar to the public, so this chapter focuses on describing three major court cases the public is already aware of, reminding us of the important role played by DNA.

The following three cases are some of the most sensational and famous uses of DNA fingerprinting. Before the use of DNA for identification, the only ways to convict someone of a crime was to have a strong motive, an eye witness, or a confession. DNA evidence has made the prosecution of a criminal and release of the innocent more probable. In the case of "The Green River Killer" DNA evidence helped to convict Gary Ridgway after twenty years of investigation. In the case of the "Boston Strangler" Albert DeSalvo confessed to all 11 of the original strangler victim murders plus 2 others, but many in law enforcement have questioned over the years whether he was the killer or if his confession was just a publicity stunt to earn money for his family. Finally, the OJ Simpson trial was probably one of the most famous cases of its time. Although that case may not have set any legal precedents, it taught us about the importance of proper DNA evidence collection and storage.

The Green River Killer

Case Background

In King County, Washington starting in 1982, dozens of women disappeared. Some were later found murdered and abandoned in various places, often in clusters, around the King County area; the other women's fates remain unknown. Many of the women vanishing were young and working as prostitutes near the Pacific Highway South (PHS). For twenty years, these deaths and disappearances were recognized as the work of the "Green River Killer", an unknown serial killer. Until 2001, the case remained unsolved even though hundreds of pieces of physical evidence were analyzed and thousands of witnesses were interviewed. Due mostly to new leads on DNA evidence, the King County Prosecuting Attorney eventually charged Gary Leon Ridgway (**Figure-1**) with four of the unsolved murders. In the year that followed, Ridgway was charged with three more of the remaining forty-five murders. After months of questioning, Ridgway admitted to most of the outstanding murder cases, and led police to his undiscovered dumpsites (Maleng, 2003).

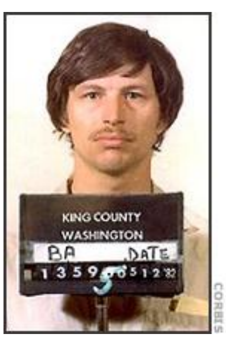

Figure-1: Mug Shot of Gary Leon Ridgway (Bell, 2011)

Charges and Plea Bargain

Gary Ridgway was arrested in 1982 (and again in 2001) on prostitution-related charges. In 1983, Ridgway became a person of interest in the Green River killings due to his known frequent presence in the prostitute scene. Also several witnesses described him and several vehicles he had access to when they were the last ones to see the victim alive. By 1984, Ridgway had taken and passed a polygraph examination regarding the murders. On April 7, 1987 police collected hair and saliva from the suspect for comparison. Detective Tom Jenson decided to take advantage of the new developments in DNA analysis by sending the evidence to the Washington State Patrol Crime Laboratory (Mateng, 2003). DNA analysis of these samples led to an arrest warrant; Gary Ridgway was arrested on November 30, 2001. Facing the death penalty Ridgway took a plea bargain which involved agreeing to confess to the Green River murders and show police where the remains of the missing victims were located (Gary Ridgway Wikipedia, 2011). King County Prosecuting Attorney, Norm Maleng explained the decision to make a deal with Ridgway:

> “We could have gone forward with seven counts [of murder], but that is all we could have ever hoped to solve. At the end of that trial, whatever the outcome, there would have been lingering doubts about the rest of these crimes. This agreement was the avenue to the truth. And in the end, the search for the truth is still why we have a criminal justice system ... Gary Ridgway does not deserve our mercy. He does not deserve to live. The mercy provided by today's resolution is directed not at Ridgway, but toward the families who have suffered so much” (Gary Ridgway Wikipedia, 2011).

On November 5, 2003, Ridgway pled guilty to forty-eight charges of aggravated first degree murder. On December 18, 2003, King County Superior Court Judge Richard Jones sentenced Ridgway to forty-eight life sentences, with no possibility of parole, and one life sentence to be served consecutively. In addition to this, he was sentenced to ten years for each of the forty-eight victims, for tampering with evidence.

Interviews

After agreeing to the terms of his plea bargain, Ridgway was interviewed for several months. During this time he admitted to all of the original “Green River Killer” murders and more. While talking about one of the victims Ridgway said, “…she didn’t piss me off for any reason, I just killed her because I wanted to.” He thought of his homicidal actions as his “career”, in fact he said he was “good at one thing, and that’s killing prostitutes.” Ridgway told the detective that he was doing the police a favor by killing these prostitutes, “…I was doing uh, like I said, doing you a favor that you couldn’t, you guys couldn’t do. You couldn’t uh, I mean if it’s illegal aliens, you can take ‘em to the border and fly ‘em back out ‘a there. But if it’s a prostitute, you’d arrest ‘em, they were back on the street as soon as they get bail and change their uh, name, and you guys, you guys had the problem. I had, I had the answer…” There were no signs during the interview process that showed that Ridgway was too mentally ill at the time of the murders to be considered not responsible for the crimes (Mateng, 2003).

Ridgway had an impulse to kill that expanded beyond just prostitutes; he admitted that he had to resist the desire to kill his wife and other family members. In fact he told the detective that his second wife was to blame for the murders because if he had been able to kill her he would have stopped at one victim. Ridgway confessed that he only discarded these thoughts because he would probably be caught if killed someone closely related to him. In his early years, Ridgway wet the bed and had vivid memories of his mother washing his genitals. His feelings toward his mother were described as a mixture of lust and humiliation. These feelings led Ridgway to fantasize about cutting his mother with a knife because of his attraction to her. In order to eliminate these urges he began stalking his female classmates on their way home from school in a state of arousal; in one case he even tried to force sex on the girl. Ridgway also admitted to killing a cat by means of suffocation and stabbing a six-year-old boy just to know what it felt like; all of these events occurred around the same time (Mateng, 2003).

The way in which Ridgway murdered his victims was described by Meteng as deliberate, methodical, and systematic. He was unrestrained by moral concerns or obligations; in fact throughout the entire five month period of interviews he showed no signs of empathy or genuine remorse for his victims. Ridgway's reasons for killing these women included: power, his evil desires, and simply just because he could (Mateng, 2003).

The Role of DNA

The police had Gary Ridgway in their sights to be the "Green River Killer" since 1983, but without any physical evidence linking him to the crime they could not charge him. In 1984, Ridgway took a polygraph test and passed which hindered the investigation. In 1987, hair and saliva from Ridgway were collected in hopes of comparison. However it wasn't until 2001 when Detective Jenson used DNA analysis on the case, showing the DNA profile in crime scene evidence matched Ridgway. Ridgway took pride in this fact, he liked that police could not convict him without this technology. He felt that no investigator had caught him, in fact in his interviews he said, "…what got me caught was technology got me caught" (Mateng, 2003). After twenty years the "Green River Killer" was finally caught. Without DNA analysis Gary Ridgway may never have been convicted of these crimes. In 2003 Ridgway was sentenced, and he will never kill again.

The Boston Strangler

Case Background

Between June 14, 1962 and January 4, 1964, an 18 month period, thirteen single women (**Figure-2**) were murdered in the Boston area by a serial killer (or many killers with a similar *modus operandi*). Eleven women most closely matched the strangler's *modus*, and were popularly known as victims of the "Boston Strangler", but two additional victims show a similar *modus*. All of these women were murdered in their respective apartment buildings, with no sign of forced entry, they were sexually assaulted, and they were all strangled with articles of their own clothing. The similar modus led the public to believe that all of the murders were committed by one single killer; however some in law enforcement believed that all of these crimes could not possibly be the work of one individual. Although there was never an official trial convicting someone as the "Boston Strangler", Albert DeSalvo confessed in detail to each of these murders leading the public to believe that he was the strangler. However, some individuals believed that Albert DeSalvo was not the "Boston Strangler", and that he confessed to make money for his family because he was already sentenced to life in prison for other crimes (Bardsley and Bell, 2003).

Figure-2: Victims of the "Boston Strangler". Shown are 13 likely victims, although 11 victims most closely matched the strangler's *modus operandi* and are more popularly known as his victims. (Corbis, 2011)

The Measuring Man and the Green Man

A few years before the murders involving the “Boston Strangler”, a series of strange instances of sexual offenses immerged in the Cambridge area. A man would knock on the door of a young woman’s apartment pretending to be a part of a modeling agency. The man would proceed to tell them that they would make a great model and they had the potential to make $40 an hour through his agency. He said that he was there to take their measurements and other information and that a “Mrs. Lewis” would contact them if they were fit for the job. If they seemed pleased with the idea he would continue into the house and take their measurements. After a while of not receiving a phone call, the women would contact the police. On March 17, 1961 Albert DeSalvo was caught breaking and entering in Cambridge. Not only did DeSalvo confess to the breaking and entering charge, he told police that he was also “The Measuring Man”. When asked why he committed the “Measuring Man” crimes DeSalvo replied, "I’m not good-looking, I’m not educated, but I was able to put something over on high-class people. They were all college kids and I never had anything in my life and I outsmarted them." He was sentenced to 18 months in prison, and was released 2 months before the “Boston Strangler” murders occurred (Bardsley and Bell, 2003).

Almost three years after his jail sentence DeSalvo was arrested again, but this time for much worse charges. He had sexually assaulted and threatened to kill a woman in her apartment. When the woman gave the sketch of the man that assaulted her, police recognized him right away as DeSalvo and took him in for questioning where he was identified by the witness. Soon after he posted bail, the police routinely put his picture through the scanner, and it wasn’t long until law enforcement from Connecticut contacted the station notifying them that DeSalvo matched the description of the “Green Man”. This man was breaking into apartments and sexually assaulting women. They gave him the name Green Man because he was wearing green pants. DeSalvo was once again brought into the station and all of the victims positively identified him as their assailant. He confessed to breaking into over 400 apartments and assaulting upwards of 300 women. Many of these instances went unreported or the victims did not want to give all of the details. DeSalvo was sent to Bridgewater State Hospital for evaluation. Shortly after his arrival he became friends with George Nassar, a dangerous murderer, this is perhaps where the strangler confession scheme began (Bardsley and Bell, 2003).

Confession

While locked up in Bridgewater State Hospital, DeSalvo started thinking about money to support his family while he served his life sentence, so he began talking to Nassar about the reward money for identifying the “Boston Strangler”. They figured among themselves that the $10,000 reward would be $110,000 after the killer of all of the eleven “original” strangler victims was factored in. They planned that Nassar would turn in DeSalvo and he would confess to these eleven murders and two others, then they would split the money. The way DeSalvo saw it, he was already going to spend a life sentence in the hospital for his current crimes; he figured he had nothing to lose if he could convince them he was mentally unstable at the times of the murders (Bardsley and Bell, 2003).

Due to his gentle manner, when his assigned defense attorney F. Lee Bailey starting interviewing DeSalvo, he could not picture him as the strangler. DeSalvo admitted during his interview, "I know I’m going to have to spend the rest of my life locked up somewhere. I just hope it’s a hospital, and not a hole like this [Bridgewater]. But if I could tell my story to somebody who could write it, maybe I could make some money for my family." Bailey wanted to ensure that he could find a way for DeSalvo to confess without being executed. When Bailey came back for a second interview, he stated "...I became certain that the man sitting in that dimly lit room with me was the Boston Strangler...Anyone experienced in interrogation learns to recognize the difference between a man speaking from life and a man telling a story that he either has made up or has gotten from another person. DeSalvo gave me every indication that he was speaking from life…” (Bardsley and Bell, 2003). In Bailey’s opinion DeSalvo knew too much information about the crime scenes not to be guilty; he knew the color of rugs, contents of photographs, floor plans of the apartments and even the placement of items in each room (Bardsley and Bell, 2003). In spite of the confession, the strangler case never went to trial, and DeSalvo was later murdered in prison.

Doubts

Many individuals had doubts that still linger today regarding Albert DeSalvo’s confession to the “Boston Strangler” murders. Susan Kelly, the author of *The Boston Stranglers*, believes that DeSalvo made up his confession because, "the newspapers were an excellent source of information - and it's very interesting to me that the details that Albert got wrong in his confession were identical to the details that the newspapers got wrong." Robert Ressler, formerly an FBI profiler, insists that there had to be more than one killer involved in these crimes because, "You're putting together so many different patterns here that it’s inconceivable behaviorally that all these could fit one individual" (Wuebben, 2001). There are additional theories that police purposely leaked information to DeSalvo in a desperate attempt to “solve” the case. George

Nassar also could have been feeding DeSalvo information as there is some speculation that he was the true “Boston Strangler”. Finally, Albert DeSalvo was a known burglar and he could have broken into the apartments after the crimes were committed and memorized the layout.

One of the main reasons many individuals argue that DeSalvo is innocent of the strangler crimes is the lack of physical evidence or eyewitnesses linking him to any of the crime scenes. It is said that the strangler was seen by a number of eyewitnesses. One of the eyewitnesses Marcella Lulka lived in the same building as victim Sophie Clark, and saw a “Mr. Thompson” who tried to paint her apartment. Gertrude Gruen, a second key eyewitness was the only woman to survive an attack by the strangler. Both of these women posed as visitors at Bridgewater and said that Albert DeSalvo looked nothing like the man they saw. However they both had their hearts drop when they saw the face of George Nassar.

In addition, some crime scene evidence does not match DeSalvo, according to author Susan Kelly, "three fresh Salem cigarette butts were found in an ashtray near Mary Sullivan’s bed. Neither Mary nor her roommates smoked this brand. A Salem cigarette butt was found floating in the toilet of Apartment 4-C at 315 Huntington Avenue in Boston the day Sophie Clark died there...Albert DeSalvo did not smoke" (Bardsley and Bell, 2003).

DNA Evidence

With all of these lingering doubts, Mary Sullivan’s body was exhumed through family consent in an attempt to find out who her true killer was. James Starrs a professor of forensic science at George Washington University was the lead scientist in creating the DNA profile. After his examination, Starrs discovered that the DNA left on the body of Mary Sullivan did not match Albert DeSalvo. "I'm not saying it exonerates Albert DeSalvo, but it's strongly indicative of the fact that he was not the rape-murderer of Mary Sullivan," Professor Starrs said (BBC News, 2001).

The case was reopened. Some of the families do not want their loved ones dug up as it brings up bad memories of the original crimes. Other families want the evidence re-evaluated. Some believe the department is stalling to avoid examination of how DeSalvo's confession was accepted in the first place (BBC News, 2001). The questions still remain, who was Mary Sullivan's true murder? Was Albert DeSalvo in fact responsible for any of the "Boston Strangler" murders? Was there more than one strangler?

OJ Simpson

Case Background

Orenthal James Simpson, popularly known as OJ Simpson, was a pro football player for the Buffalo Bills, known for shattering records for the most rushing yards in one season and most yards per game in a single season. At the age of 30, OJ met Nicole Brown, who was 18 at the time, working at a nightclub in Beverly Hills. When they first met, Simpson was married to his first wife, Marguerite L. Whitley, and had three children: Arnelle, Jason, and Aaren, who sadly drowned just shy of being two years old. After his divorce in 1979, Simpson married Nicole Brown on February 2, 1985. They later had two children: Sydney and Justin (Jones, 2004).

In 1992, after seven years of marriage, and several accusations of domestic abuse, Nicole Brown Simpson filed for a divorce. Two years later, she began spending a lot of time with Ron Goldman, an aspiring actor ten years younger than her. Early on the morning of June, 13 1994, just after midnight, Nicole Brown Simpson and Ron Goldman were discovered brutally stabbed to death in Nicole's home. Blood was found in several locations on the property including the stairs. The two bodies were found side by side, Nicole was discovered with gashes in her upper body and throat, and Ron was stabbed 22 times (Jones, 2004).

Figure-3: Victims of OJ Simpson. Left: Nicole Brown Simpson, and Right: Ron Goldman. It is commonly believed that OJ Simpson committed these murders despite the not guilty verdict. (Jones, 2004)

The Murder

On the night of the murder, OJ and Nicole attended their daughter Sydney's dance recital separately. When OJ returned home he had a conversation with Brian "Kato" Kaelin, a friend of Nicole's and a resident at OJ's estate. They talk about how Nicole and OJ are not "together anymore" and how her and a friend were wearing "tight" outfits at the recital. OJ and Kaelin go to McDonald's, then part ways to eat. After the recital, Nicole ate dinner with friends at Mezzaluna where her friend Ron Goldman works. When she got home she realized that her prescription sunglasses were left at the restaurant, and Ron agrees to bring them to her after work (OJ Main Page, 1995).

Later that night, Allan Park arrived at OJ's estate to bring him to the airport. He rang the buzzer around 10:40 PM, but got no answer. At 10:55 PM Nicole's neighbor found her Akita dog unattended, with bloody paws, and it seemed agitated. At 10:56 PM, Park saw a white male (Kaelin) carrying a flashlight investigating a noise that he heard. He also saw a 6-ft tall, 200-lb black person cross the driveway in the background, wearing dark clothes, and enter the house. After speaking to Kaelin, Park rang the buzzer again and this time got a response. At 11:45 PM Simpson flew from Los Angeles to Chicago (OJ Main Page, 1995).

The next morning at 12:10 AM, Nicole's neighbors were led to the murder scene by her dog; they described seeing the blood flowing like "a river". Around 4:30 AM the police went to OJ Simpson's estate supposedly to notify him of the murders. While they were there, they discovered a blood stain on his Ford Bronco and more stains leading toward his house. They also found a bloody glove that seemed to match the other glove found at the murder scene. Police saw that a light was on inside the house, and assumed that people were inside. They called the security company to get the phone number to the house, but when they called they received no answer from inside. The police went to Kaelin's room to wake him up and checked his shoes for blood. When they find nothing they woke up Arnelle Simpson who was staying in the guesthouse and he opened the house for them. Simpson was contacted in Chicago; he checked out of the hotel at 6:30 AM. A judge issued a search warrant for the Simpson estate; when he arrived home OJ is arrested and brought into the station for 3-1/2 hours of questioning (OJ Main Page, 1995).

DNA Evidence

No two people can have the exact same DNA unless they are identical twins. DNA samples taken from blood at the crime scene were compared to the samples taken from OJ

Simpson, Nicole Brown Simpson, and Ron Goldman. The prosecution prepared the samples to testify against OJ Simpson, claiming that the tests they completed link OJ to the murders. The defense on the other hand claimed that the samples taken from the crime scene were contaminated or could have been planted, therefore making the evidence inadmissible in court (OJ Main Page, 1995).

The blood stains in question were collected from OJ Simpson's white Bronco, on socks found in his bedroom, on the pair of gloves (one found at the crime scene, the other in his driveway), the crime scene, and in his house. One of the most critical pieces of evidence in the trial was the gloves found drenched in blood. The left-handed glove was found outside of Nicole Brown Simpson's home, and the right-handed glove was discovered in the OJ Simpson estate. During the trial, Simpson was asked by the prosecution to try on the gloves, and when they were too small the prosecution said that the gloves shrunk from being covered in blood. Of course the defense claimed that if the gloves didn't fit then OJ didn't commit the murders (OJ Main Page, 1995).

Trial

The trial took almost nine months of testimony to complete. There were about 120 witnesses, 45,000 pages of evidence and 1,100 exhibits. Despite this fact, the 12 jurors including: ten women and two men; nine African Americans, two whites, and one Hispanic, only took about four hours to reach a not guilty verdict (Cable News Network, Not Guilty, 1995).

OJ Simpson's team of lawyers was led by Robert Shapiro, and featured attorneys F. Lee Bailey, Alan Dershowitz, Robert Kardashian, and others. The chief prosecutor in the case was Marcia Clark who told the jury in her opening statement that forensic evidence would prove that

Simpson was guilty. When witness Brian “Kato” Kaelin did not account for OJ’s whereabouts as expected, he was treated as a hostile witness and asked if his testimony had changed (Jones, 2004).

The focal point of the forensic evidence was the gloves covered in blood found at both the crime scene and OJ Simpson’s house. When OJ tried to put the gloves on to prove that they matched, they did not fit his hands. The prosecution claimed that shrinkage had occurred once the gloves were drenched in blood; the defense attorney Johnnie Cochran on the other hand argued, “If it doesn’t fit you must acquit”. LAPD Detective Mark Fuhrman gave testimony that he found one of the gloves on Simpson’s property. However, he was discredited once he was caught up in the lie of using a derogatory word against black people, and the defense argued the glove was placed there as a way to frame OJ Simpson (Jones, 2004).

Verdict and Reaction

On October 3, 1995, the verdict was read to the courtroom; OJ Simpson was acquitted in the murders of Nicole Brown Simpson and Ron Goldman. As each verdict was read, Simpson mouthed “thank you”. Behind him his family member cried tears of joy, and Ron Goldman’s family wept in despair. Prosecutors carefully watched the jurors as each one was individually asked if the verdict was correct; they all agreed. Judge Lance Ito announced before the jurors entered the courtroom that they did not want any news contact over the events of the trial. Precautionary measures were taken before the verdict was read to allow for extra police coverage and Federal law enforcement if necessary (Cable News Network, Not Guilty, 1995).

After the previous not guilty verdict of the Rodney King case was read, the inner-city erupted with riots and destruction. The defense used this knowledge to persuade the mostly black jury that the evidence the police gathered against Simpson was false. Polls showed that blacks and whites look at the Simpson case very differently: six out of ten blacks think that OJ Simpson was innocent, whereas three out of four whites think that he was guilty. If the outcome of this case had been different, reactions would vary greatly. If OJ was convicted, there would have been an appeal that could have taken years. If the jury was deadlocked, there would have been another long trial. Many believed that once acquitted, Simpson could make millions of dollars to explain his side of the story to the public (Cable News Network, Not Guilty, 1995). About 73% of the population believed that the verdict would have been guilty had OJ been poor; 57% of people believe that the jury reached the verdict too quickly. Approximately 80% of the people polled watched the verdict unfold (Linder, 2000).

Other OJ Crimes

Simpson was subsequently found guilty in a civil lawsuit filed by Ron Goldman's father, and found liable for the deaths of Nicole Brown and Ron Goldman, but OJ he never served any time for the murders. Thirteen years after the 1995 criminal not guilty verdict, OJ Simpson finally had to serve prison time for a crime. This comes as a big relief to the people who did not agree with the outcome; they feel slightly at ease knowing that he didn't get away with murder after all. The crime that finally caught OJ in a mess ironically had to do with him leading an armed robbery to reclaim his possessions from sports collector in a Las Vegas hotel room. The civil law suit left OJ about 23 million dollars in debt, but the debt was never paid. OJ never bothered to get a job knowing that the money would go straight to the Goldman's and the Brown's. The only attempt Simpson made to get money was a "hypothetical" account of the murders called "If I Did It – Confessions of the Killer". But this plan failed due to public outrage; later the Goldman family published the book after the court awarded them the profits. Based on the robbery guilty verdict, Simpson was locked up in solitary confinement to protect him due to his fame. The earlier murder trial had an effect on the robbery case, mostly because one of the items Simpson was trying to regain was the suit he wore the day that the verdict was read. In the robbery case, Simpson was found guilty by an all-white jury, and in response to this his lawyer said that it was only “payback” for the 1995 trial. Simpson appealed the robbery case using the premise that he was essentially being re-tried for the murders (Gardner, 2008). So the questions remain, did OJ really murder Nicole Brown Simpson and Ron Goldman? Was the jury biased in favor of OJ? Did the robbery verdict have anything to do with the original not guilty verdict of 1995?

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Chapter-5: DNA Database Ethics

Jessica White

DNA databases are depositories of DNA information in computers. However, not all DNA databases are alike. Forensic databases contain only identifying information, and help match profiles found at crime scenes to past cases or to previously arrested individuals. Medical databases contain far more information, and help scientists determine which genes are associated with specific diseases. This chapter will focus on understanding what DNA databases are, why they are used, the information included in them, and the ethics surrounding their use.

Before DNA databases can become widely accepted, the general public has to have an understanding of what they are, how they work, and what benefits come with their use. Often people confuse the differences between a CODIS database and a genetic database, assuming the same privacy rights and ethics should apply to each. The only information that can be taken from a database is the exact information that was originally input, no more. This information becomes increasingly important when debating the ethics behind database privacy rights.

CODIS vs. Genetic Databases

The Combined DNA Index System or CODIS is software used to run and maintain the FBI's criminal forensic DNA databases, including the entire program of software support for local, state, and national laboratories. The National DNA Index System or NDIS is one module of the CODIS program. The original purpose of the CODIS pilot project was to create a database of convicted offender DNA profiles to assist in solving cases in which there are no suspects. This program worked so well it surpassed its original mandate by now including a large Forensic Index of profiles from unsolved crime scenes, while some states even allow *arrestee* databases. CODIS began in 1990 with 12 state and local forensic labs; today it has 153 participating labs representing 49 states and the District of Columbia. As of early 2002, CODIS helped solve over 4,719 crime investigations in 31 states and two federal labs (Adams, 2002).

As discussed in Chaper-1, the information entered into CODIS includes, at best, identification information from the 13 core loci. Unlike common perceptions, the 13 core loci do not contain any known medical predisposition information, and were carefully chosen by medical geneticists for that reason, and the fact that the sites vary considerably between individuals. Thus, throughout this chapter it is important to note that no medical information can be hacked from CODIS.

On the other hand, there are medical or genetic databases. The government of Iceland has a genetic database that includes health and genetic information about Icelanders. The information in this database is required by law and cannot be removed. At the start this project, only medical and family histories were included, but resistance to the bill increased when the government added genetic information to the pool (Hloden, 2000). Their Parliament rationalized this addition with the idea that certain diseases can be inherited through genes, so medical databases eventually allow scientists to create medicines to fight genetic diseases. A contract was granted to deCODE, a biomedical company, to research genes correlated with over 30 diseases including: heart attacks, emphysema, and Alzheimer's disease. deCODE planned to publish the information gathered from the Icelanders' genetics to the internet in order to cross reference it with family history and medical records.

The main problem with medical databases becomes privacy; the database could allow abuse to the access of this information, such as insurance companies denying coverage to individuals determined to be predisposed to a disease. The argument is that each individual's genetic information is encrypted; however codes can be hacked and figured out (Hloden, 2000).

Probability of a CODIS Match

The CODIS system allows for investigative advances in a case where DNA evidence is collected at a crime scene, but no suspects are apparent. Matches in the Forensic Index can link multiple crime scenes together with the possibility of identifying serial offenders. This allows police from multiple jurisdictions to combine their evidence to develop new leads not noticed previously. As the information input into the system increases, for example adding new convicted offenders to the database, so does the probability to finding a match to the evidence collected at a crime scene (CODIS Brochure, viewed in 2011).

As discussed in Chapter-1, the analysis of a DNA sample collected from a suspect or crime scene yields a DNA profile; a complete CODIS analysis includes information from all 13 core loci. When DNA is analyzed for CODIS, it is not sequenced from beginning to end, that has only been completed a few times in history. A full genomic sequence is expensive, and is not needed to create an identification profile. The profiles submitted to CODIS contain information collected from 13 Short Tandem Repeat (STR) loci. The STR loci allowed in CODIS were specially chosen for identification in law enforcement because they are not linked directly to any genetic or medical traits. Throughout the history of CODIS, it quickly became apparent that the larger the database, the more accurate scientists understand the allele frequencies at each locus, so the more accurate becomes the match (**Table-I**) (Adams, 2000).

	Offender Profiles	Forensic Profiles	Investigations Aided	Forensic Hits	National Offender Hits	State Offender Hits	Total Offender Hits
2000	460,365	22,484	1,573	507	26	705	731
2001	750,929	27,897	3,635	1,031	167	2,204	2,371
2002	1,247,163	46,177	6,670	1,832	638	4,394	5,032
2003	1,493,536	70,931	11,220	3,004	1,151	7,118	8,269
2004	2,038,514	93,956	20,788	5,147	1,864	11,991	13,855
2005	2,826,505	126,315	30,455	7,071	2,855	18,664	21,519
2006	3,977,433	160,582	43,156	9,529	4,276	28,163	32,439
2007	5,372,773	203,401	62,059	11,750	6,508	43,305	49,813
2008	6,539,919	248,943	80,948	14,122	8,479	58,304	66,783
2009	7,688,286	298,369	101,766	17,636	10,969	75,186	86,155
2010*	8,646,417	328,067	119,764	19,940	12,791	89,598	102,389

*Through July 2010

Table-I: List of CODIS DNA Database Statistics. This table shows the number of offender and forensic profiles in the database, the number of investigations it has assisted in, and the number of "hits" discovered (CODIS Brochure, viewed in 2011).

Usually a DNA investigation includes a comparison of two samples, for example an unknown piece of evidence from a crime scene versus a known suspect sample. If the DNA profiles of these two samples are identical, then it can be used as evidence in court that they are from the same origin. If the profile has a rare combination of traits (a match at all 13 core loci) that match the suspect then the evidence is strong; but if the similarities are common traits they could match by chance. It is thus very important when a match occurs that there is an understanding of the probability that the match could have occurred by chance (Brenner, 2004).

The **Table-II** details the probability that a particular locus could have been matched coincidentally. For example allele 6 at locus THO1 in this case was discovered 102 times in a population sample size of 428 alleles, equaling 214 people. Based on this data, one can estimate that the there is a p=0.24 possibility that any THO1 collected arbitrarily could be a 6. Likewise, the probability that a random THO1 allele will be 7 is approximately q=0.15. Assuming that the suspect is not the donor of the evidence we think of him as someone who inherited a THO1 allele from his parents. The probability of getting 6 from his mother and 7 from his father is represented by *pq*; similarly, receiving 7 from his mother and 6 from his father is a second *pq*, therefore the possibility to be 6,7 by chance is 2*pq*. About 7% of people have the 6,7 genotype on the THO1 locus. In the vWA locus, both alleles are the same so there is one term represented by *pp* or p^2 for the allele 16 from each parent. Therefore approximately 5% of the people have the same vWA genotype. The overall chance for two people to have the combined genotypes in both loci is 7% of 5% or about .35%. The calculations for the other two loci are similar; once all four example loci are taken into account, the chance of two people having the combined genotype is approximately 0.00014 (0.014%) or 1/7000 (Brenner, 2004). When all 13 core loci are analyzed, the probability goes to one in several billion.

DNA Profile		**Allele Frequency from Database**				**Genotype Frequency for Locus**	
Locus	Alleles	times allele observed	size of database	Frequency		formula	number
CSF1PO	10	109	432	*p*=	0.25	2*pq*	0.16
	11	134		*q*=	0.31		
TPOX	8	229	432	*p*=	0.53	p^2	0.28
	8						
THO1	6	102	428	*p*=	0.24	2*pq*	0.07
	7	64		*q*=	0.15		
vWA	16	91	428	*p*=	0.21	p^2	0.05
	16						
			profile frequency=				**0.00014**

Table-II: DNA Match Probability. This table shows an example of the way a profile is matched in a database and how frequent the match occurs by chance (Brenner, 2004).

DNA Database Ethics

Originally the CODIS Offender Index included only the profiles of convicted sex offenders and other violent criminals. But it was quickly learned that not all crimes can be solved with the information given by previous sex offenders and violent criminals. In fact, when Virginia expanded their system to include samples from all felons, the success rates of solving crimes sky rocketed. A large number of their "hits" were obtained through the profiles of burglars, drug offenders, or other nonviolent criminals (Adams, 2000).

Whose DNA is Entered?

In the United States, whose DNA is entered into CODIS is dictated by individual states. In accordance with the DNA Identification Act of 1994, all felony offenders are entered in the National DNA Index. Over the years, state legislatures have actively been increasing the profiles allowed in their DNA databases. Over half of the states expanded the offenses included in their databases. And the larger the database, the more accurate allele frequencies can be assigned to individual populations, including ethnic populations.

But an unfortunate side effect of allowing more samples into CODIS is the backlog of samples ready for analysis. In some states, there is not enough time and resources to process all of them. The Federal government has made attempts to help with this set back with the DNA Analysis Backlog Elimination Act of 2000, but the backlogs likely will persist as the databases expand further (Adams, 2000).

The types of profiles entered into CODIS can be categorized by several indexes. A Convicted Offender Index includes the DNA of individuals convicted of crimes. The Arrestees

Index contains DNA of arrested people, if the state in question permits the collection of this type of evidence by law. The Forensic Index includes DNA developed from crime scene evidence, which can include profiles from hair, blood, semen, etc. The Missing Persons Index contains reference DNA from a person's belongings to help investigators locate them. Biological Relatives of Missing Persons Index contains samples from relatives of the person in question that willingly donate DNA to assist in the investigation. Finally, Unidentified Humans (Remains) Index contains DNA profiles developed from unidentified evidence at military sites (CODIS Brochure, viewed in 2011).

The people required to submit DNA to the database are enforced by laws at the state level rather than a federal level. Currently, all 50 states require that convicted sex offenders provide DNA for the database. Approximately 45 states require all committed felons to be added to the DNA database. Approximately 36 states require some juvenile criminals to be added to the DNA database in hopes that if they become a repeat offender later in life their DNA can be matched. Only 16 states require misdemeanors to go into the system, and most of them have specific guidelines as to which crimes are serious enough to require submission. About 15 states allow some arrestee DNA profiles to be documented, but again it is only for specific crimes. There are 9 states that allow a profile to be documented if the person is found not guilty by a mental defect or GBMI. Finally, some states will include other DNA profiles of people who have committed crimes such as burglary, weapons violations, and drugs. Massachusetts specifically allows all felonies and some misdemeanors to be added to their DNA database (National Conference State Laws, 2005).

In my opinion, the state laws that are the most effective in DNA database collection come from the state of Colorado. Their requirements include all felonies and some juveniles; I believe that in serious crimes, DNA profiles are necessary for helping convicting repeat offenders. In conjunction with these laws, Colorado also, "Includes any person who has a duty to register as a sex offender, including probationers, habitual offenders as condition of parole, and those released without parole supervision" (National Conference State Laws, 2005). The reason that this addition is beneficial is that the state can use less manpower supervising people on parole knowing that catching them committing a subsequent crime might be easier. If their DNA is found at a crime scene they can now be linked to the area in the event that they become repeat offenders.

Privacy Rights

From a crime solving point of view, the more samples in CODIS the more likely a crime will be solved. So from this perspective, having *everyone's* profile in the database would help solve crimes. But most people are against this, as it violates an innocent person's privacy. Convicted felons do have some rights to privacy, however they should have fewer rights than innocent people if they have committed a serious crime. Convicted felons no longer have the right to withhold their DNA from analysis by the state, but they still have the right to semi-private housing. When people argue against including convicted felon profiles, they need to ask themselves what happened to the privacy rights of the person that was just raped or murdered. The fourth amendment to the constitution protects people from having to surrender their DNA without probable cause and a search warrant. The amendment states:

> "The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized." (US Constitution- Fourth Amendment, 2008).

One of the biggest concerns of the general public is that insurance companies and employers can gain medical information from the database, thus hurting their chances of success or coverage. This is not the case with CODIS since, as stated earlier, the only information that can be taken out of a database is what was put into it. For CODIS, this includes only the identifying information of the 13 core loci that have been regulated by the government and do not contain any medical or genetic information. However, it is true that medical information might be obtained by analyzing the original DNA sample stored in the lab freezer. A solution to this issue could include the enactment of a law requiring the state to destroy the original DNA sample after accurately recording the information needed from the 13 core loci.

The security of DNA databanks is very important in gaining the acceptance of their use. The entire process requires safety measures for the storage of original DNA samples, database security, and security protecting against people linking the two pieces of information. Because this creates many potential areas where an individual's privacy can be compromised, databases require extensive security precautions including audit and accountability measures (Genetic Privacy, 2009).

The potential reuse of a stored DNA sample for research is a very controversial topic. Some people suggest that since these samples can contain information about predisposition to disease that it can be used to link specific genes to genetic disorders to help cure the disease. However, the use of these DNA samples originally acquired for CODIS or without the consent of the individual is inappropriate for good information practices. Although some argue that people convicted of a crime may lose some civil rights, this isn't the case for people who were arrested for a crime and never got convicted but still have their DNA samples stored in forensic databanks. There is a theory that this kind of research can be conducted as a secondary use if the samples have been de-identified, protecting the person that the sample belongs to. The argument refuting this is that DNA can never fully be "de-identified" unless it is compromised to not include any identifying material. The storage of DNA for people never involved in a crime is another questionable area. Some people will willingly consent to their DNA sample being taken to eliminate them as a suspect. Some of these people do not realize that their identification profile might be kept in the database from that point on; the use of this information for solving future crimes could compromise their privacy (Genetic Privacy, 2009).

The use of DNA for medical research yields many risks to the privacy of the person that provided the sample: potential discrimination in health insurance, discrimination in life insurance, discrimination in employment, and involuntary disclosure of a condition. Unfortunately in the eyes of health insurers "good business" requires them to charge higher rates and limited insurance to people at high risk of developing diseases. If information about a person's genetics is released, they could receive fewer benefits if it shows a risk of an expensive disease, regardless of whether the person ever truly shows signs of having the illness. Some life insurers have asked individuals to take genetic tests for similar business practices. Employers are more likely to hire workers who will remain healthy and can continue working for a long period of time. In companies where the employer contributes a portion of the cost of health and life insurance, healthier employees are the key to saving money. Some states have made laws to protect employees from discrimination based on their genetic makeup. With the increase of take-home DNA kits, the risk of people being tested without informed consent is more likely. Discarded objects with DNA may be used for testing, violating the privacy of the individual in question (Privacy Rights, 2009).

Chapter-5 Conclusions

Overall, the use of DNA databanks can be very beneficial in crime scene investigation and law enforcement. States are actively increasing the amount of DNA profiles required in their databases because of the realization that the bigger the database is, the higher the probability of receiving a match. The author of this chapter best likes the laws of the state of Colorado that currently requires profiles for all convicted felons, all sex offenders, and some convicted juveniles.

Regarding privacy rights, there is a common mix up between CODIS versus genetic databases. Some people believe that genetic predisposition information can be found in CODIS, but that database includes only identifying information found in the very carefully chosen 13 core loci. The government regulates the 13 STR loci selected for CODIS, and these loci have no medical or genetic information other than unique identifying information.

However it is true that medical information could be taken from the DNA original sample stored in the forensic laboratory freezers. To prevent this, laws should be passed requiring the destruction of the original DNA sample once the identifying profile has been entered into CODIS. This will protect some of the individual's privacy rights, making people more accepting of CODIS DNA database use.

For medical databases, despite the fact that this type of research can assist in identifying genes related to specific diseases, if such databases are created, it is critical to obtained informed consent, fully informing them that if their genetic and medical information passes into the wrong hands, health insurance providers, life insurance providers, and possibly employers could inappropriately use the information.

Chapter-5 Bibliography

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PROJECT CONCLUSIONS

There are two main types of DNA fingerprint testing, one is the non-amplifying RFLP technique, and the other is STR-PCR. The benefits of the RFLP version is that it is not strongly affected by outside DNA contaminants, it is more reliable, and it results in more accurate results. The down side to this technique is that it is time consuming, and requires an ample supply of DNA. So the RFLP type technique is often used for paternity testing where DNA samples are readily available. The STR-PCR technique is currently the most common method used for DNA testing because it is fast and does not require a large sample size. With the use of PCR amplification of STR loci, very small samples (even the DNA from only one cell) are enough to perform the test. The fault in this method is it can easily be contaminated, the contaminating DNA will be amplified along with the forensic sample. Sometimes *both* techniques are used for critical criminal cases when sufficient DNA is present at the crime scene.

Avoiding DNA contamination is one of the greatest issues in forensic sciences. This is why much effort has been spent developing standard and rigorous sample collection and storage procedures. Maintaining a sample "chain of custody" is also important to document exactly who has handled the evidence in case contamination is observed. Each person that handles a piece of evidence must sign the sheet, and describe what they used it for, so that contamination can be tracked and prevented whenever possible.

Since its invention in 1985, as DNA fingerprinting became a more accepted science and began to make its way into the court room, precedents were established for admitting complex DNA evidence in trials. The most current standard is a rigorous 5-prong test developed from *Two Bulls v State* (1990) which combined three previously separate standards. The standard requires a pre-trial hearing to determine whether the DNA technique used is generally accepted in the scientific community, is reliable, was performed properly, and whether the evidence is prejudicial. This pre-trial hearing must be performed for every case to determine whether the DNA evidence for that case can be entered in court.

With respect to whose DNA profiles should be entered into the CODIS database, the authors of this project agree with a controversial stance currently being considered by some states that all U.S. citizens should have their DNA placed in the CODIS database at time of birth. This would greatly aid the police investigators in determining the culprit in many crimes. We feel this would drop crime rates, since almost any DNA evidence collected at a crime scene would help lead to a conviction.

With respect to privacy rights and worries about hacking into CODIS, since a DNA profile entered into CODIS contains only information on the 13 core loci used only for identification purposes, no hacker could gain medical information from that database. Thus, the authors do not fear that information being stolen. We do however agree that the original chemical DNA samples should be destroyed after their use and input into the CODIS system, as those samples if used inappropriately could contain medical information. This would prevent any unwanted medical information from being acquired without the permission and knowledge of the donor. For medical databases (not CODIS) which contain medical information, donation to such databases should not be mandatory, and should be done only with informed consent.