IQP-52-DSA-8651

DNA FINGERPRINTING AND SOCIETY

An Interactive Qualifying Project Report

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

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October 22, 2007

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ABSTRACT

The purpose of this IQP was to investigate DNA Fingerprint Technology and its effects of society. Different procedures for DNA Fingerprinting were described, as well as the many uses of this technology, leading into the forensic applications and the collection and preservation of samples. Landmark court cases were discussed showing a progression of acceptance of complex scientific evidence in the courtroom. A few notable DNA media cases were described as a reference to the power of the technique. Finally the ethical issues of DNA databases were discussed focusing on the main concern of genetic privacy, an important issue affecting the growth of DNA database technology.

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PROJECT OBJECTIVE

This project was designed to examine recent developments in DNA fingerprinting technology and to show its effects on society. These techniques have many uses and are making great strides in the advancement of forensic science. The acceptance of complex scientific techniques such as DNA fingerprinting in the courtroom is just starting to take off due to a variety of controversial issues, as documented in several landmark cases. This new advance in science will hopefully help convict the guilty and exonerate the innocent. Extensive research of DNA fingerprinting procedures, collection and preservation of samples, documented advancements and set backs in the courtroom, and ethical issues involving the advancement in DNA databases have been investigated for this project.

CHAPTER-1: DNA, THE BASIS OF LIFE AND ITS USE IN FINGERPRINTING

All characteristics of a person, such as hair and eye color, blood type, skin color, and facial features are determined by genetic information inherited from a mother and father. This information is contained within a twisting ladder, a double helix consisting of strands of linked nucleotides, in a structure called deoxyribonucleic acid, or DNA (Nobel Prize Foundation, 1993).

Nucleotides contain one of four bases; A-adenine, G-guanine, T-thymine, and C-cytosine. These bases combine to form base pairs, attaching A-T and G-C. Reading the sequence of letters down one side of the strand, such as GAACGT (shown in Figure-1, starting from the top left), is a code that stands for a trait specific to the individual. Each person's DNA is different from every other individuals, except for identical twins, which share the same DNA. It is for this reason that DNA fingerprinting is such a valuable tool

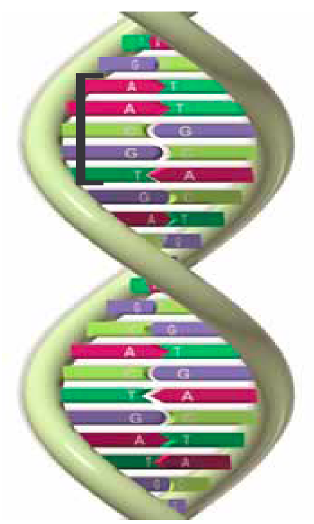


Figure-1. Diagram of a DNA Double Helix.
http://www.harunyahya.com/dna02.php

in identifying and distinguishing between individuals, and making a breakthrough in forensic science (Betsch, 2007, pg.1; National Institute of Justice, 1999, pg.1).

The entire DNA contents of a human cell is called the genome, and it contains approximately 3-6 billion base pairs. Of this only about 0.1% varies from person to person, making us unique. Different DNA sequences are found on our cell's 46 chromosomes at different locations or loci. The variation at these loci are called alleles and the genetic differences that come from the loci are known as polymorphisms. These polymorphisms are what makes each of us different and create an individual's DNA fingerprint (Lee, 2003, pg. 4-6).

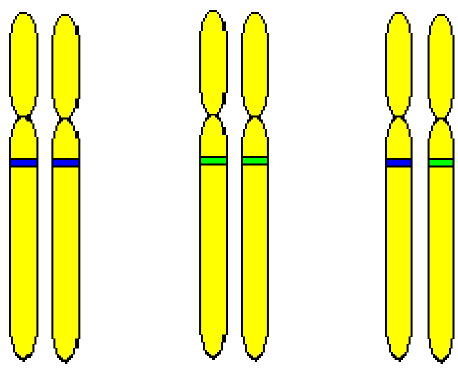


Figure-2. Chromosomes and alleles. *http://digilander.libero.it/avifauna/articoli_ornicoltura/cromo3.gif*

VNTRs and RFLPs

Genes are the protein-coding regions of DNA, but scientists focus on the non-coding regions, or "junk DNA" for fingerprinting analysis. These "junk" regions make up most of our DNA. Sir Alec Jeffery's analysis of this junk discovered a component called variable number of tandem repeats, or VNTRs (Lee, 2003, pg. 6). VNTRs are sequence domains fifteen to thirty five base pairs long that are repeated next to themselves anywhere from one to thirty times (Lee, 2003, pg.6). The number of repeats are different from person to person, and this difference in VNTR lengths is measured in a VNTR-type fingerprint. The different number of repeats in turn creates DNA strands of different lengths that can be compared to other DNA samples (UCLA lecture notes, 2004, pg. 1; Meeker-O'Connell, 2004).

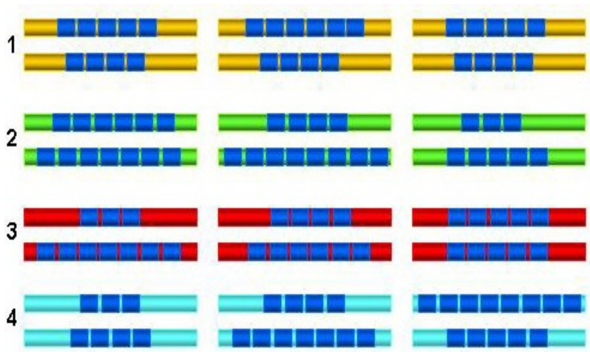


Figure-3.Variable Number of Tandem Repeats. *http://www.ucm.es/info/genetica/grupod/Cromoeuc/vntr1.jpg*

The analysis of these VNTR repetitive elements is called restriction fragment length polymorphism (RFLP) analysis. This non amplifying technique uses restriction enzymes to cleave the DNA at specific sites unique for each type of enzyme. To analyze these DNA strands, a sample of DNA needs to be recovered from the body. It can be extracted from blood, semen, skin cells, tissue, organs, muscle, brain cells, bone, teeth, hair, saliva, mucus, perspiration, fingernails; found in almost every cell in our body (National Institute of Justice, 1999, pg.1).

Figure-4. DNA Blood Sample. *http://www.fdle.state.fl.us/CrimeLab/images/dna%20feathered.jpg*

Once a sample of DNA is isolated, a restriction enzyme is chosen to digest the strands, such as EcoRI (found in *E. coli* bacteria) that cuts DNA at the sequence GAATTC. The enzyme cuts the DNA at the restriction sites removing fragments of various lengths from the DNA. These DNA fragments are separated by size in a process called electrophoresis. The separated fragments are blotted to a membrane and the specific fragment of interest is then identified by hybridizing it to a single stranded probe with a complementary sequence. The combination of the restriction enzyme and the probe sequence produce a series of bands when a southern blot is performed (Davidson College, 2006).

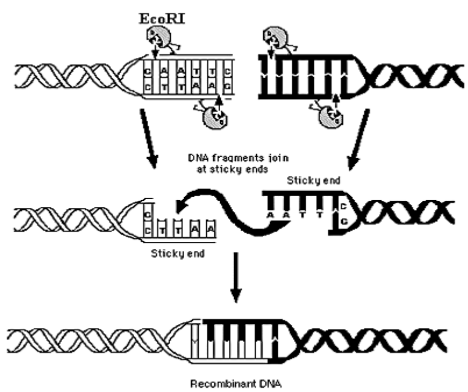


Figure-5. Restriction Enzyme EcoRI.
http://accessexcellence.org/RC/VL/GG/restriction.html

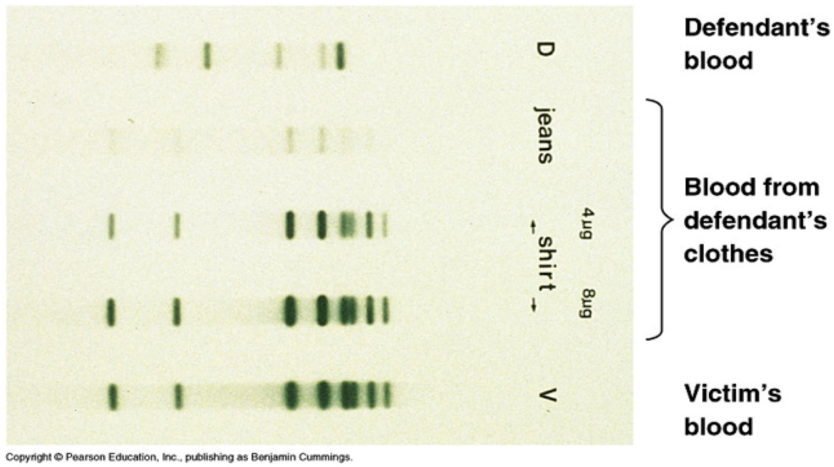


Figure-6. DNA Fingerprint.
http://fig.cox.miami.edu/~cmallery/150/gene/20x12fingerprint.jpg

The membrane is washed to get rid of excess probe, then the location of the probe on the membrane is determined using X-ray film (Santa Monica College, 2007, pg. 4). Several probes can also be used to create a more complex DNA fingerprint. The more probes, the more loci are analyzed, so the more accurate the DNA fingerprint is in determining which person it belongs to (Betsch, 2007, pg. 2; UCLA Lecture Notes, 2004).

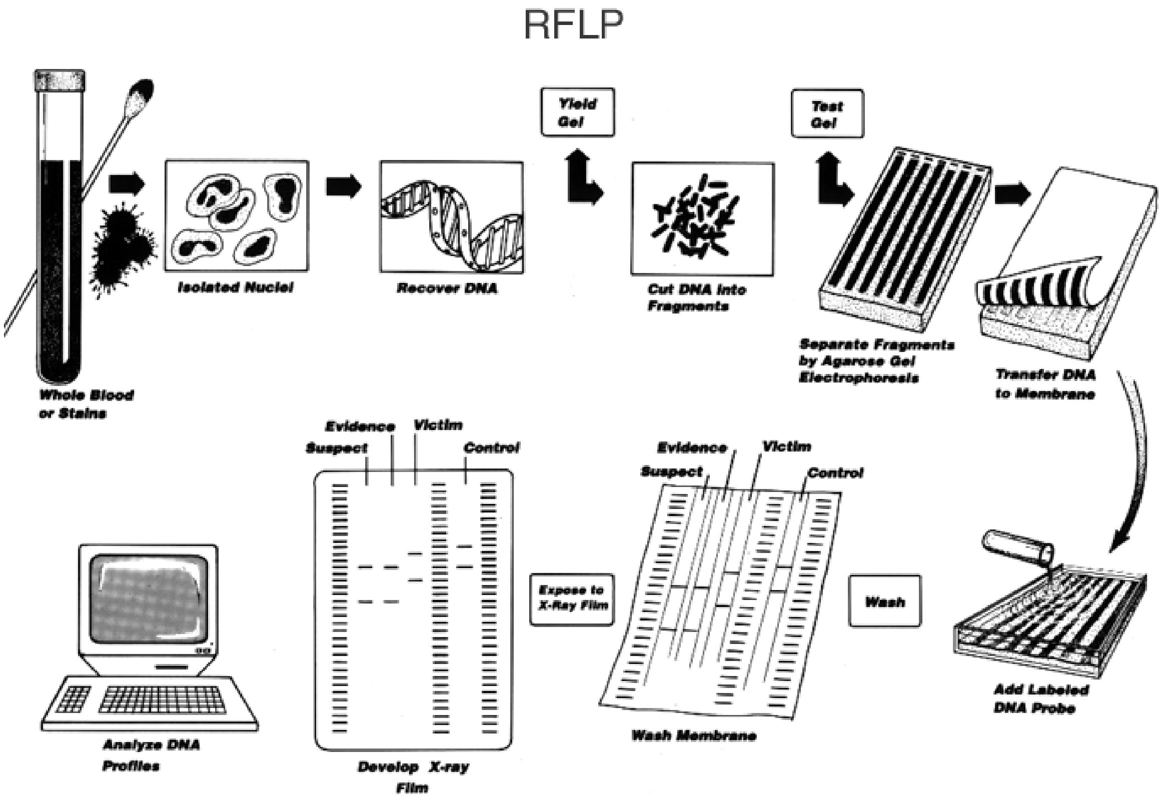


Figure-7. RFLP Method.
http://www.ul.ie/tap/StudentWebProjects/Fiona%20Murphy/Tech%20Awareness

STRs and PCR Type Fingerprints

Another type of VNTR, called short tandem repeats or STRs, contains a repeating domain only two to seven base pairs long. STR analysis is a more preferred method of DNA fingerprinting over RFLP analysis because: 1) STRs are more numerous than the longer VNTRs, so there are potentially more loci to analyze from a given DNA sample, and 2) these strands are shorter than VNTRs so they can be amplified by PCR, allowing DNA analysis to be performed when only a small sample of DNA, such as a single hair follicle, is available (Lee, 2003, pg. 6-7).

PCR, polymerase chain reaction, is a controlled DNA replication process that allows for copies of a trace amount of DNA to be made in a short amount of time. These copies can be separated by electrophoresis, characterized and analyzed easier than RFLP analysis. Since PCR makes copies of DNA using primers, part of the DNA needs to be known. Somewhat like the restriction enzyme sites in RFLP, locations flanking a target sequence use primers specific to that loci. There are thirteen core loci that the FBI currently use when analyzing DNA, and each locus has a unique sequence. Thus a unique primer sequence must be used to begin replication at that locus.

Before the primers can be attached, the DNA must be separated into two individual strands by heat, in a process called denaturing. Once the strands are separated, the primers are added, one hybridizing upstream from the locus being amplified, and one hybridizing downstream. The DNA is cooled which allows the primers to attach to the DNA template. To form the new strands, a mixture of the four nucleotides (adenine, guanine, thymine, and cytosine), and an enzyme called *taq*-polymerase (which doesn't break down in the presence of heat) is added. The nucleotides attach to the DNA to form new base pairs with its corresponding nucleotide (A-T, G-C) on the strand until two complete strands of DNA are formed. This cycle can be repeated to get an exponentially growing amount of the DNA sample (Brown, 2006, pg. 2). PCR is an amazing technique that gets results fast and easily, but because it is so sensitive, contamination can be an issue (Kimball, 2007, pg. 1-2). As long as PCR is performed carefully and accurately, contamination by other DNA sources can be minimized.

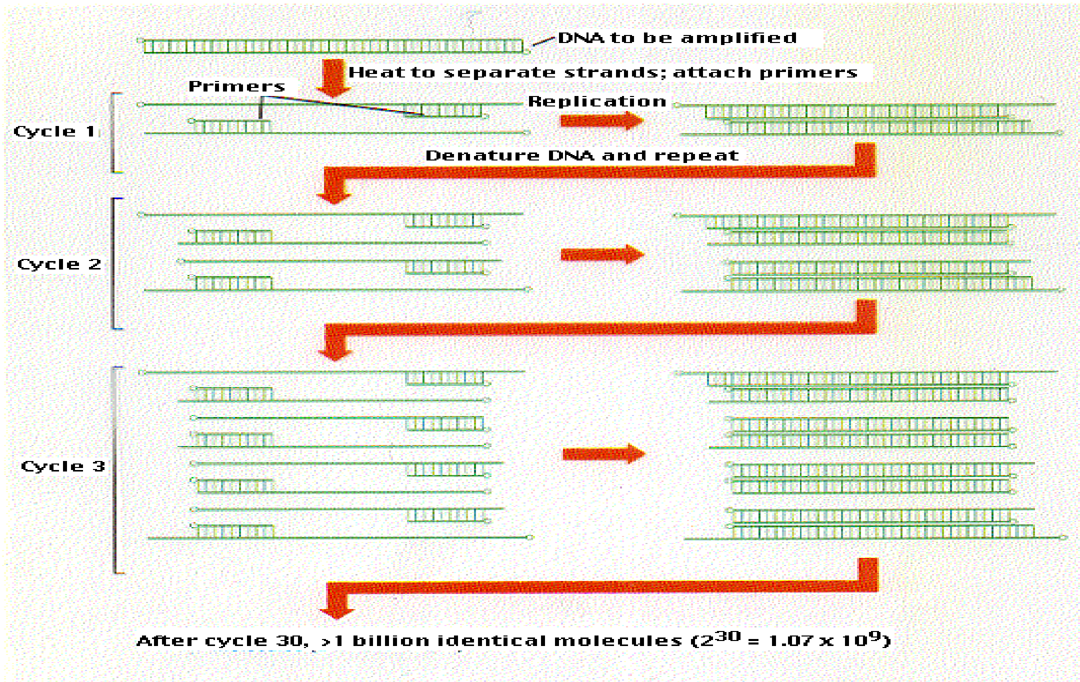


Figure-8. PCR. Kimball. Kimball's Bilogy Pages.
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/PCR.html

DNA Fingerprint Technology Uses

These remarkable advancements in DNA fingerprinting technology has allowed us to advance in many different areas of science. Using the method of DNA amplification of PCR, a new field has emerged, molecular archeology. Extracted DNA from biological remains, skeletal remains, teeth, and sometimes fossils are amplified using PCR and compared to other samples. Scientists are discovering new information about ancient cultures and organisms (Christianson, 2000). Anthropologists have used DNA typing to compare DNA from important people who died many decades earlier to those in the present to determine potential relationships. One famous case used DNA to disprove a woman who claimed to be Duchess Anastasia, daughter of Nicholas the Czar of Russia, thought by some to have escaped execution. Scientists are also using DNA typing on fragments of the Dead Sea scrolls to reconstruct the pieces as they existed originally (Biotechnology Industry Organization, 2003, pg. 2).

A more recent use of DNA fingerprinting is the use in the World Trade Center disaster. Tissue samples from the wreckage have been collected and are being used, as much as possible, to extract DNA to identify the victims of the attack. Missing people that were in the building are being identified by comparing known samples from victim's personal effects or relatives. Unfortunately not all samples have DNA that can be used in typing due to burns and decomposition, and some people left no DNA trace at all. But using this science, scientists are doing the best they can to identify those lost to the tragedy (WTC Disaster Identification, 2001).

One of the most widely used cases for DNA fingerprinting is paternity testing. The child's mother's and alleged father's DNA fingerprints are compared to the child. In the child's profile, the mother's alleles are ignored, leaving the father's to be deduced. If they match then he is the child's father (Biotechnology Industry Organization, 2003, pg. 2). Figure-9 shows a paternity test on one loci between Payle and Jack, Payle's alleged father. Because the bands between Jack and Payle are the same, this concludes that Jack could be the father of Payle. Upon more loci tests, a more accurate conclusion as to the paternity of the child can be made.

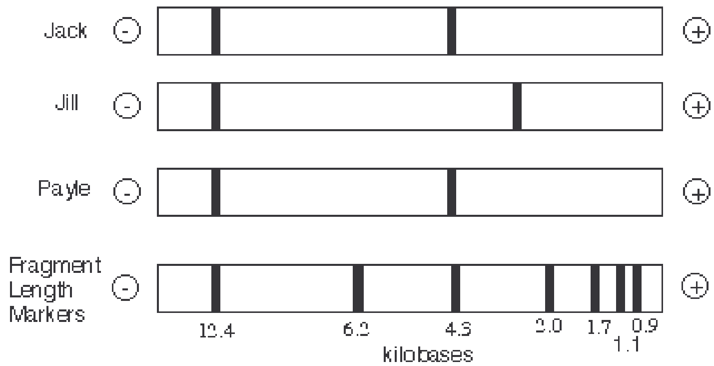


Figure-9. Sample Paternity Test. Davidson College (2006).
http://www.bio.davidson.edu/courses/genomics/method/RFLP.html

The biggest use of DNA typing is in forensic science. The first use of DNA typing for law enforcement purposes was in Great Britain in the 1980s, and was introduced to the United States in 1987. The FBI now handles most DNA typing for local and state law enforcement agencies. DNA evidence has been used to convict the guilty, or to clear wrongly convicted people who were charged in crimes before DNA typing was widely used. The FBI has thirteen standard loci that are currently tested, and the probability of two people (except identical twins) with the same DNA fragments at all thirteen locations is less than 1 in 1 trillion people (Kimball, 2007, pg. 2). It is with this accuracy that the FBI can use DNA evidence to assure the real offender is convicted. Some states have started to require military, government personnel, and violent criminals, such as rapists and murders, to submit their DNA to a data bank known as CODIS (discussed later) so evidence can be compared to known offenders or be matched to that of a victim. This system allows for a rapid comparison to help speed up the process of fingerprinting (Biotechnology Industry Organization, 2003, pg. 1-2).

Chapter-2: DNA Forensics

For the technology of DNA fingerprinting to grow so rapidly since 1987, the collection, preservation, and examination of DNA evidence has had to become a virtually flawless process, especially since mishandled DNA evidence can completely ruin individual court cases, as shown with the O.J. Case (discussed later). Scientists known as CSI (crime scene investigators) are responsible for the proper handling of this delicate material. It is important that these scientists follow established procedures to the letter, to ensure that the DNA results are accurate and non-contaminated. Most cases now rely on the 99.99% accuracy of DNA fingerprinting to help convict the correct people. Mistakes in the specific details of the DNA evidence procedure can cause the samples to be inadmissible in court, and people to be set free, or wrongly accused.

Crime Scene Protocol

When a call comes in to the police they proceed to the area of concern. The first person on the scene has the important duty of securing the scene. They are responsible for identifying the scene and securing an area larger than the suspected scene by physically blocking it off. This is to prevent people from walking on to the area and disturbing any possible evidence that may be present. Normally crime scene tape (see Figure-10) is used to create the boundaries, and police often stand by to ensure further protection (Byrd, 2000, pg.1).

Figure-10. Photo of CSI Personnel Gathering Crimescene Evidence. Naval Medical Center Portsmouth, VA. Layton. How Stuff Works (2004)
http://www.howstuffworks.com/csi1.htm

With a secure scene, the person in charge can now begin the investigation processes. This head person makes the decisions, organizes the crime scene and directs the personnel. An initial walk-through of the scene is done to survey the potential hazards, see if anything has been moved, observe evidence possibilities, and create a pattern in which to collect the evidence. Everything is to be documented in a narrative, a description of everything occurring at the crime scene. It details every part of the investigator's responsibilities, case information, scene conditions, and the position and condition of evidence. Along with the written or audio documentation, photographs and sketches are used to detail the narrative.

Figure-11. Bullet Evidence to Scale.
http://www1.istockphoto.com/file_thumbview_approve/3945636/2/istockphoto_3945636_crime_scene_evidence_photo.jpg

The photographs of the scene should be taken as quickly as possible to ensure the accuracy of how everything was found. A log is recorded which includes the description and location of all the evidence and the photographs for each. A name, date and labels of the evidence should be on everything, and the photographs should be taken in an overall, medium and close up view, and next to a ruler for a scaled comparison. The overall photographs of a crime scene need to show a 360 degree view of the area using a series of overlapping pictures and need to be taken of the interior and exterior. Every room needs to be photographed from all four corners of the room and the outside of the building, as well as the entrances and exits. When taking pictures of the exterior, landmarks should be present to show the relation of the building to other objects. All people at the scene should also be photographed. It is possible that one of those people could be a witness or suspect (Layton, 2004, pg 2).

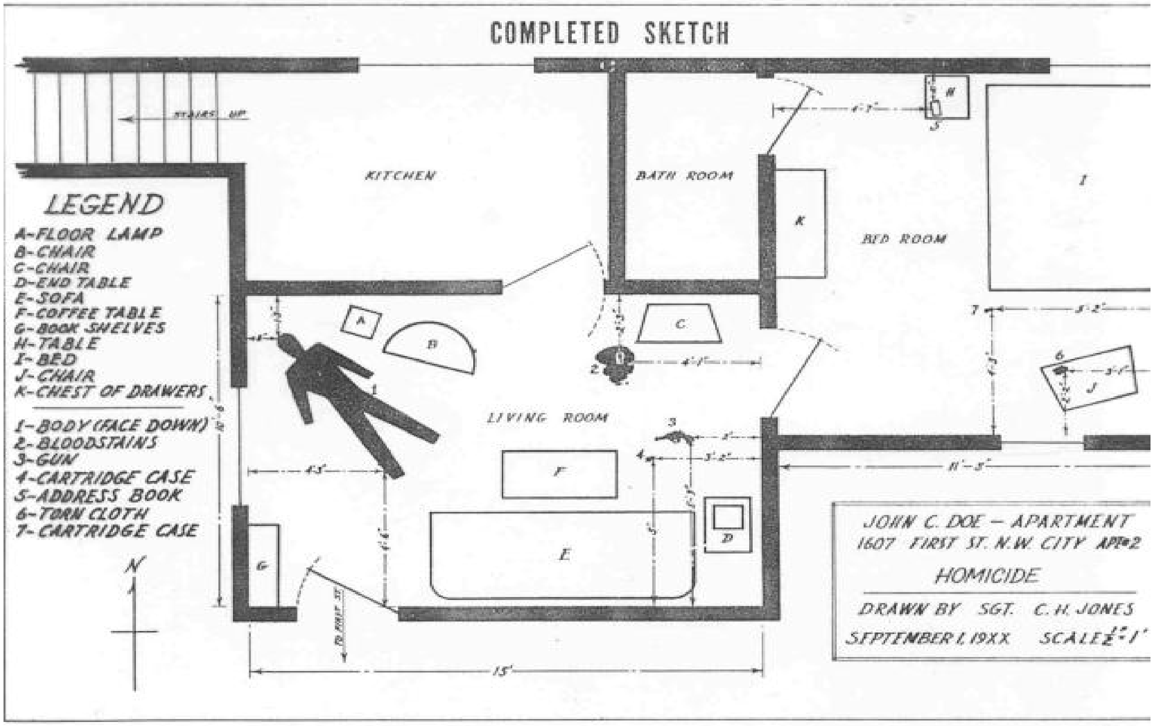


Figure-12. Crime Scene Sketch.
http://www.sccja.org/csr-csmgmt.htm

Sketches are simple drawings of the crime scene. They are used to show the scene as is, show evidence positions to each other, and measurements. Dimensions of the scene, entrances, windows and furniture need to be shown, as well as measurements between items and the location of evidence from at least two stationary points such as walls or doors (Federal Bureau of Investigation, 1999, *Handbook of Forensic Services*. pg. 155-165; Byrd, 2000, pg.3-4).

When evidence is being photographed and logged, how do CSI's know what to look for? There are many different types of evidence that can be found at a crime scene: trace evidence (small pieces of material such as gun shot residue) (GSR), broken glass, chemicals, hairs and fibers, impressions (fingerprints, footprints, shoe prints and tool markings), ballistic evidence (weapons, bullets, casings, etc), biological evidence (semen, vaginal fluid, blood, saliva, vomit and epithelial scrapings) (ex. skin under a victims fingernails), document-type evidence (computers, answering machines, cell phones, planners, diaries and notes, and also general physical evidence that doesn't really have a category because it can be specific to the type of crime scene (an example being a pill container in a drug related case or suicide, or larger pieces of evidence that may have smaller evidence on it as well).

While examining a crime scene, the same path needs to be taken to ensure that nothing is disturbed on the scene. There are many different paths CSI's use to search a room to ensure full coverage (Figure-13). A spiral search working from the outside in or inside out (upper left panel in the figure) ensures 360 degree coverage and keeps you constantly looking in different directions. A parallel search (upper right panel) works in one direction across the entire room. A grid search (lower left panel) is a better coverage search than parallel, as it works parallel in two directions overlapping each area. A zone search (lower right panel) splits up the room into sections for different CSI's to search, and allows them to switch zones for better coverage (Layton, 2004, pg. 1-4).

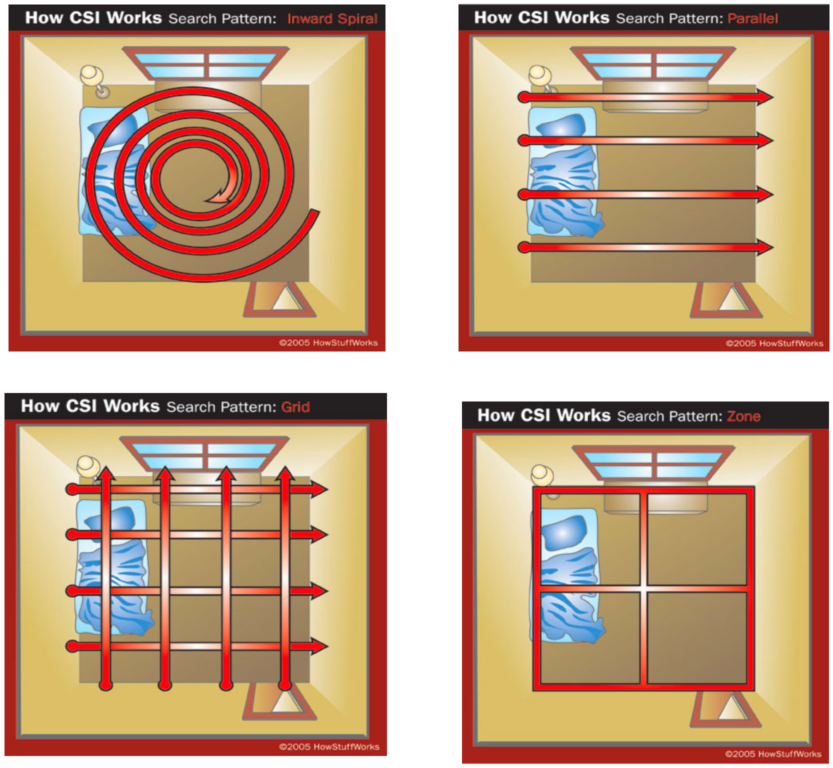


Figure-13. Diagrams Showing Various Paths for Analyzing Evidence at a Crime Scene. Layton. How Stuff Works (2004)
http://science.howstuffworks.com/csi.htm

Evidence Collection

Evidence collection is the slowest process in crime scene investigation. Everything needs to be handled with the utmost care to ensure there is no contamination and that it is packaged and shipped properly. CSI's have to reduce the possibility of leaving their own DNA while collecting evidence. Gloved hands keeps them from leaving any fingerprints, protective glasses are worn when using UV detection lights or handling certain chemicals, protective outer clothing is also worn to prevent exposure to possible chemicals and materials at the crime scene. When collecting evidence, limited contact is a key. Use gloved hands and thoroughly cleaned tools, do not talk, cough or sneeze while collecting evidence (saliva can come in contact and compromise DNA evidence), do not touch your face or hair and change gloves often to avoid contamination (National Institute of Justice, 1999, pg. 3).

Figure-14. Evidence Collection Kit.
http://www.evidentcrimescene.com/cata/kits/kits.html

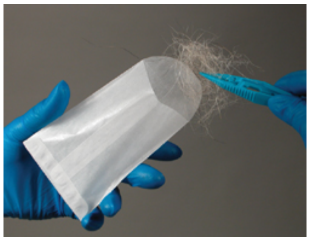
Different types of evidence require different tools and techniques in the collection and preservation of samples. If a gun shot victim is found, for example, to contain possible trace evidence, clothing would be collected and packaged in a paper bag and sealed. These samples would be taken to the lab to be examined for GSR. Tweezers and knives are generally used to pick up or scrape trace evidence into paper envelopes or plastic containers. Soil, paint, glass, unknown powders, and other such material are air dried and sealed in separate, sterile containers. All evidence containers are labeled with the CSI's name, date, evidence information and location before being sent for analysis.

Trace Evidence

Hair and fibers are a subset of trace evidence. They are generally found on larger pieces of evidence such as a body, clothing, bedding, or other similar objects. Combs and tweezers are used to collect this small evidence and place them into collection envelopes. Sometimes a small filtered vacuum is used to collect possible hairs and fibers from difficult places. When hair or fibers are found, a control sample should be obtained and sealed in a separate package. If a red fiber is found on a body at a scene, a fiber from a red pillow in the room is a good control sample, these known samples are used for comparison to the evidence. Hairs that have been pulled from the roots can be used as a source for DNA evidence. If a victim pulled hair from the attacker in a struggle, possible DNA evidence from the root could link the victim and suspect.

Bulky Evidence

Documents are collected with gloved hands and are sorted and put in separate bags (Figure-15). Other evidence such as computers, answering machines, or bulky evidence can be placed in boxes or large bags. All evidence should be separate and many large items can be searched for prints later. Weapons should also be collected with gloved hands, and picked up in places where prints are less likely to be found to avoid smudging or wiping away prints. When fire arms are used, CSI's can use laser trajectory kits to determine the height the shot was fired from, where the victim was in relation to the shooter, and other important information from the bullet holes found.



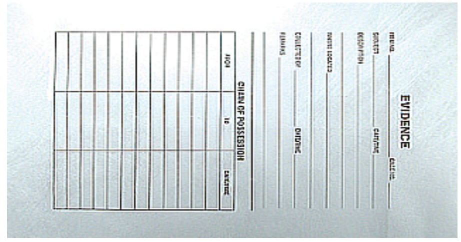


Figure-15. Photos of Evidence Collection Envelops.
http://www.evidentcrimescene.com/cata/evid2/evid2.html

Castings and Molds

Many times footprints, tire treads and tool marks are obviously unable to be lifted at the crime scene and placed in an evidence bag, so they are mainly collected by making molds of the marks. Sometimes the items with the marks or prints are small enough to be taken to the lab, like the tool markings on a bomb segment for instance, but most of the time footprints are left in dirt, or marks are made during a forced entry on a window sill or door. These pieces of evidence require a casting of the imprint to be made on the scene. A CSI uses casting compound (like gypsum) and water to create a compound mixture, and gently pours it down the side of a casting frame to keep air bubbles from occurring and from getting an uneven print. The mixture needs to dry over the impression for at least thirty minutes before being removed. Once it is dry, it is carefully lifted and placed into a bag for transport without cleaning the casting, to ensure no loss of evidence.

Figure-16. Casting Frame .
http://www.evidentcrimescene.com/cata/cast/cast.html

Unfortunately, footprints are very rarely found to be complete (Figure-17) because prints come out differently when people are walking, or running, or slipping, or many other reasons why a print can come out less than perfect. However, it is possible to tell from these molds some unique characteristics by the way the foot made an impression. People's weight distribution, injury, or other issues can cause unique wear on the underside of a shoe leaving an equally unique impression.

Figure-17. Photo of a Footprint Mold. Harris, 2004, Page 2.

Unfortunately taking a casting of a tool mark is not as reliable. It is better to take the entire piece with the markings to the lab than to make a mold; castings of tool marks are more difficult to use for comparisons. If a mold is needed, silicone-rubber cast is made over the marks, allowed to dry and placed into a collection bag. Tool marks can be classified as either an impression or striation.

Figure-18. Side-By-Side Tool Mark Comparison. Baltimore Police Laboratory Division. *http://mysite.verizon.net/vzesdp09/baltimorepolicehistorybywmhackley2/id36.html*

Impressions occur when a hard object comes in contact with a softer surface leaving an indentation on the tools shape in the surface. Striations are left when a back and forth motion was made using the tool. The tool leaves a series of parallel lines on a surface and makes for a very nice comparison sample. Tool marks can be compared to see if the same tool made both impressions or the marks can be compared to a tool in evidence to determine if that tool made those markings.

Fingerprints

Fingerprints are left everywhere with non-gloved hands, anything someone's fingers touch leave a mark in the shape of their own unique fingerprint. Sometimes fingerprints are left in solids or liquids, and leave a visible or molded print. Other prints, that are not normally visible are called latent prints. These prints are left when the oils and sweat from a person's fingers comes into contact with a surface. To reveal prints left on porous surfaces such as paper and cardboard, chemicals (iodine, ninhydrin, or silver nitrate) are sprayed onto the surface or object. Prints on glass, polished wood, plastic and other non-porous surfaces are brought out with powders (Figure-19). These prints are very delicate and can be destroyed by friction so the best way to avoid damaging prints is to not touch where there may be prints.

Figure-19. Photo of Fingerprint Powder and Brush. Layton. How Stuff Works (2004)
http://science.howstuffworks.com/csi4.htm

If the surface the print is on is dark in color, then a metallic silver powder is used to distinguish the print, if the surface is a light color, then black velvet powder is used. To avoid destroying the prints, the powder is applied with a long bristled brush in small circular motions. When a print is revealed, the powder is lightly brushed in the direction of the print ridges. A small bristled brush is used to carefully remove excess powder and provide better clarity. After the powder has been applied, fingerprints are then photographed and recorded. All suspects, victims, and personnel on the scene must also have fingerprint cards made up to eliminate them at the scene.

Figure-20. Latent Print Collection.
http://goldenladyunlimited.com/academicstandards.html

To lift the fingerprints, transparent tape with a black or white background card, or black and white rubber lifts are used. The colors of the background need to contrast with the powder being used, black powder with white backing, or silver or white powder with black backing. The tape is placed over the print and smoothly removed in one direction and motion, it is then adhered to the backing card for transport.

For lifting prints on small or obscure objects, fuming is done to reveal the prints. The object, a plate with super glue and a heat source (which needs to reach about 120 degrees F) are placed into an air-tight container and heated; the fumes of the glue reveal prints on the object (Layton, 2004, pg. 1-6).

Biological Evidence

Biological evidence is some of the most sensitive evidence at a crime scene. Improper collection, preservation or transportation can contaminate DNA found in the samples. DNA evidence is most likely found in blood, semen, saliva, vomit and epithelium (skin scrapings). Biological evidence is comparative evidence and needs to have reference samples from the victim and suspects (whenever possible). The DNA found in the evidence at the scene of a crime will be compared and hopefully matched to the reference samples.

Blood is going to be found at most murder scenes and even violent crime scenes, but what makes the collection of blood samples different at each scene is the type of contact made during each crime. Blood exchange can happen between the victim and assailant when they are in close proximity to one another. If the victim fought back there is most likely going to be blood from the victim found on the suspect and possibly the suspect's blood on the victim. If there was a stabbing or beating, there was most likely blood exchange and CSI's should be aware of this when collecting evidence. Blood anywhere away from where the victim was found, as well as a samples from close around the body should be collected, as well as a sample from the victim themselves. If it appears a struggle occurred, blood could also be found on the victims knuckles or under their fingernails.

Blood is a biohazard material, unless it is tested, you can not know what could be in it and how it can affect a person it comes into contact with. As with any evidence collection, proper safety clothing and sterile equipment should be worn and used. Because DNA is involved, changing gloves often, and cleaning tools before and after collecting samples is proper technique. When collecting liquid blood samples from a suspect or victim, medically trained personnel collects at least two 5mL tubes of blood in a vacutainer with a purple cap. These tubes contain an anticoagulant (EDTA) that prevents the blood from clotting. Each tube is properly labeled and packaged in a Styrofoam container and kept refrigerated. The styrofoam tube must also be labeled "BIOHAZARD", kept refrigerated, and kept in a cool, dry place (Schiro, 2001, pg. 3-4).

Figure-21. EDTA Vacutainer of Blood.
http://www.behdarou.com/products.htm

Liquid blood at a crime scene is the most likely blood sample to contain DNA. It has been untouched and has not yet dried, so it is probably less likely to be contaminated. To collect liquid blood samples a sterile cotton swab or cloth is used to absorb some of the blood leaving part of the swab unstained as a control. Once the swab is dry it can be placed in a paper evidence bag and transported for analysis. The same procedure is used when collecting already dried blood samples. However, the collecting swab should be wet with distilled water to adhere the dried stain (US Department of Justice, 2007, pg. 36).

The use of water to collect dried blood unfortunately dilutes the stain, possibly reducing the amount of DNA available. If the blood is found on a hard surface, a combination of scraping and tape lifting can be used to reduce any contamination. A thoroughly cleaned spatula can be used to loosen the dried on blood and scrape the flakes into a paper envelope. Scraping may make the pieces of dried blood hard to handle so a tape lift can be used to collect the loosened flakes and adhere them to a piece of vinyl acetate, not paper. Bloodstains on clothes or objects should be if possible sent to the laboratory as a whole piece of evidence. If the object is too large, a cutting of the stain and a control cutting should be packaged separately and sent instead (Schiro, 2001, pg. 8-10).

Figure-22. Bloodstained Clothing.
http://mvn.com/mlb-orioles/2007/04/26/schillings-bloody-sock-a-

Blood patterns can be of more use than just providing DNA. The spatter of blood at a crime scene can help CSI's discover what may have happened and how the blood became where it was found. Some types of common blood patterns used are gravitational (blood falling to the ground), slash/line (indicates a possible slashing movement), spray (possible blunt contact in that direction), and others.

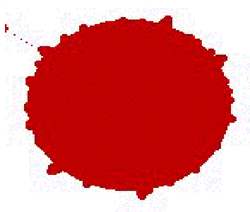


Figure-23. Gravitational/Low Velocity.
http://www.deviantcrimes.com/bloodspatter.htm

Figure-24. Slash/Line.
http://www.istockphoto.com/imageindex/407/8/407872/Blood_splatter.html

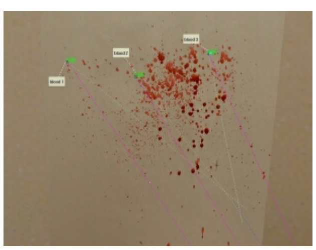


Figure-25.Blood Spray.
http://www.deltasphere.com/deltasphere_crimeaccident.htm

Sometimes CSI's arrive at a crime scene where someone has tried to clean up after the incident. Sometimes blood is not visible or very dilute. If this is the case, no DNA evidence can be obtained, however the confirmation of blood could help get a warrant for some other evidence. Luminol is often used to bring about diluted or cleaned bloodstains (Figure-26). Luminol is a water based chemical that when applied to blood will glow in the dark (figure right panel). Bleach can also cause luminol to glow which could be an indication that someone tried to remove a bloodstain with bleach (Harris, 2004; (Schiro, 2001, pg. 4).

Figure-26. Picture of Luminol at Work. Harris. How Stuff Works (2004).
(The right panel shows luminol-stained blood glowing in the dark. The left photo show the same scene in normal light).
http://www.howstuffworks.com/luminol1.htm

In sexual assault cases the biggest biological asset is semen. UV lights are used to isolate stains which allows for separate stains to be tested. Collecting semen is just like collecting blood. For liquid semen a cotton swab is used leaving a portion of the swab unused as a control. The samples are air dried, and then packaged in a paper envelope. Dried semen stains can be either adhered with a moistened swab or cut pieces of evidence can be submitted. To collect sexual assault evidence from a victim, a medical examination using a sexual assault evidence kit is used by trained medical personnel to collect vaginal, oral, and anal evidence. Again, biological evidence is easily degraded, and should be refrigerated.

When a suspect is found, a cheek swab (buccal swab), is performed to collect DNA evidence. Cheek swabs are very simple and less intimidating to the person receiving the test than blood drawing. A cotton swab is rubbed on the inside of the cheek from an individual that has received no food or drink for at least twenty minutes prior to testing (Kramer, 2002, pg.3). Saliva can also be found on cigarette butts, chewing gum, stamps or envelopes, masks, etc. For smaller evidence such as chewing gum or cigarettes, cleaned forceps are used to collect the sample. Once air dried, the sample is packaged in a paper envelope and labeled. Larger evidence should be collected with gloved hands, packaged separately, and labeled in a paper bag. Buccal swabs do not need to be refrigerated (US Department of Justice, 2007, 37-43).

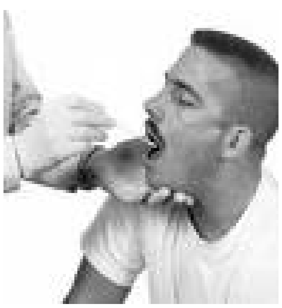


Figure-27. Collection of DNA Using a Buccal Swab .
http://shop.armorforensics.com/mm5/merchant.mvc?Screen=CTGY&Store_Code=RedWop&Category_Code=2778

Chapter-3: Landmark Court Cases

DNA evidence, as well as traditional evidence such as fingerprinting, handwriting analysis and trace evidence, have greatly improved the criminal justice system and its ability to prosecute the correct person for the crime and helping solve old cases. OJ Simpson and other very well known murder cases (discussed in Chapter-4) could not have used DNA technology as a part of the case unless previous landmark cases before them had set a precedence for allowing complex technical evidence in U.S. courts. These cases set the standard for DNA evidence and what is admissible in court.

Scientific progress is difficult to track, new theories and ideas are being discovered, created and tested all the time. Many things we never thought possible are beginning to make sense and lead to further discoveries. Scientific evidence in the courtroom was also initially difficult to accept since the technique has not always held general acceptance in the scientific community. In 1923, during the court case of Frye vs. United States, scientific evidence in the court room took its first real steps.

Frye vs. United States

In this court case, the defendant was convicted of murder in the second degree. The defense wanted to bring forth an expert witness to testify to the results of a new systolic blood pressure deception test (similar to the modern day polygraph test) which the defendant had undergone. The theory behind this test is that blood pressure is related to the changes in emotion of a person, and that nerve impulses are sent to the autonomic nervous system creating a rise in blood pressure. It is claimed that this occurs when a conscious falsehood, concealment, or guilt is accompanied by fear of being caught. It is believed that if the truth is being told, blood pressure starts high with the pressure of the exam and diminishes as the test proceeds. However, if lies are being told, when fear of being caught arises, the blood pressure increases throughout the exam.

The presentation of the defense counsel of this evidence stated: “ 'The rule of the opinions of experts or skilled witnesses are admissible in evidence in those cases in which the matter of inquiry is such that inexperienced persons are unlikely to prove capable of forming a correct judgment upon it, for the reason that the subject-matter so far partakes of a science, art or trade as to require a previous habit or experience or study in it, in order to acquire a knowledge of it. When the question involved does not lie within the range of common experience or common knowledge, but requires special experience or special knowledge, then the opinions of witnesses skilled in that particular science, art, or trade to which the question relates are admissible in evidence.' ” In other words, if common knowledge is incapable of providing correct judgment, then an expert in that field can testify as evidence.

This Frye rule had been used in many subsequent cases, but when a “principle or discovery crosses the line between experimental and demonstrable stages is difficult to define.” It was decided that science behind the evidence must be “...sufficiently established to have gained general acceptance in the particular filed in which it belongs. We think the systolic blood pressure deception test had not yet gained such standing and scientific recognition among physiological and psychological authorities as would justify the courts in admitting expert testimony deduced from the discovery, development, and experiments thus far made." The lie detector evidence was denied and the original guilty judgment was affirmed.

This case set a standard in the courts known as the Frye standard. The admissibility of a scientific technique must be analyzed by the scientific community from which it came, and once it is agreed that the technique is based on sound theories, it would then be allowed in court. This standard was used in many other techniques such as voice prints, gunshot residue tests, blood grouping tests, and more (Green et al, comment on Frye v. United States, 1923; Forensic Psychiatry, 2007).

Many courts thought the Frye standard was too harsh. In 1975 the Federal Rules of Evidence was drafted, and Rule 702 was created as a more lenient standard for admitting newer techniques as evidence. It allowed for expert witnesses to testify if techniques are shown to be reliable, not necessarily 'generally accepted'. This reliability rule is brought out by the case of United States v. Downing (1985).

United States vs. Downing

In this case, the defendant was convicted of mail fraud and interstate transportation of stolen property. He was convicted solely on eyewitness testimony as evidence. The defense was denied an expert witness testimony on the unreliability of eyewitness testimony. This court did not use the Frye test, but used many factors to determine the reliability of eyewitness testimony; "the relationship of a new technique to establish modes of scientific analysis; the existence of a specialized literature dealing with the new technique; the qualifications and professional stature of expert witnesses; the non-judicial uses to which the scientific technique are put; and the frequency with which a technique leads to erroneous results." Because the results of studies in this field had been found to be inconsistent, and there was lack of testimony of the methodology used or the data the results were based on, the court found the defense's witness unreliable and inadmissible in the court as evidence.

If the court had found the evidence reliable, it would have then considered whether the evidence would have overwhelmed, confused, or mislead the jury. The lacking testimony of data and methodology results were seen to be a risk for misleading the jury, and was also involved in the denial of evidence admissibility. The court also determined that the "fit" of the expert testimony in the court was weak, and that the reliability of the eyewitnesses could be determined through cross examination and common sense. This case was a stepping stone in the court's ability to dismiss evidence from a case that is not relevant, could confuse the jury, or is found unreliable (United States v. Downing, 1985).

First Court Appearance of DNA

DNA is one of the most amazing scientific breakthroughs and has many uses in numerous fields. However, in court it was still a new and unique technique in the mid-1980's. Alec Jeffreys was the father of DNA fingerprinting. He discovered that each person has a unique DNA fingerprint that can identify them by comparing lengths of DNA with repeating VNTR cores.

The first use of this technology in court was a paternity test in 1985, for an immigration case, and Jeffery's did the DNA testing himself. A UK citizen was returning to his mother and siblings after a visit to his original home in Ghana, but official's said his passport was forged and he faced deportation. It was believed that this boy was not closely related or even related at all, but DNA fingerprint analysis proved that all of the boy's DNA bands matched those of the mother, her children, and the father. The case was dismissed and the family was reunited (University of Leicester, 2007, pg. 3).

The Colin Pitchfork Case

The first murder conviction based on DNA evidence and the first person to be proven innocent by DNA occurred two years later in 1987. In 1983, in a small city outside of Leicester UK, called Narborough. A local fifteen year old girl, Lynda Mann, was discovered brutally raped and strangled. The only evidence was a small sample of semen. The case went unsolved for four years. In 1987, another fifteen year old girl, Dawn Ashforth, was also found brutally raped and strangled and the similarity of this case to Lynda Mann's case proved they were looking for the same person.

A tip led police to a seventeen year old dishwasher, Richard John Buckland. He was taken into custody and questioned. There he admitted to killing Dawn Ashforth, but denied Lynda Mann's murder. Police needed something to link the two murders to Buckland, so Jeffreys' technique of DNA fingerprinting was used to prove his guilt of both murders, by comparing his DNA to the semen found at the scenes. But unbelievably the DNA cleared Buckland of the charges, he was not the murder.

Since DNA fingerprinting proved Buckland innocent, police turned the search in a different direction. Every male between certain ages in local towns, were to be tested with blood samples. The media had gotten a hold on this case and a woman came forth to the police that she overheard a man bragging in bar that he paid someone to take the blood test in his place. Colin Pitchfork (Figure-28) was brought into custody and admitted to the crimes. His DNA was compared to the semen in both cases, and was found to be a match, making him the first person to be convicted with DNA evidence (Batt, 1999, pg. 1-2; HBO Forensic Features, 2004).

Figure-28. Photo of Colin Pitchfork. HBO. The Black Pad Killer (2004).
http://www.hbo.com/autopsy/forensic/the_black_pad_killer.html

First U.S. Murder Case: Andrews vs. Florida

Soon after the first murder conviction in the UK using DNA evidence, the technique was used in a United States court case. In 1989, Tommie Lee Andrews was convicted in the state of Florida with DNA evidence. A mistrial was called due to a lack of statistical evidence. Evidence was provided during the retrial and was deemed admissible in court. Upon review of the US v. Downing, and Rule 702, the evidence and techniques of DNA fingerprinting were shown to be reliable as it was used for other uses prior to evidence. The jury took this into consideration among other reliability issues and convicted Andrews (Congress of the US Office of Technology Assessment, 2007, pg. 1).

People vs. Castro

In 1987 Vima Ponce and her Daughter were stabbed to death. A handyman for the neighborhood, Jose Castro was questioned and a bloodstain was found on his watch. Samples were taken from the victim's and the watch and sent to Lifecodes for testing. The prosecution wanted to admit the DNA evidence and the results showing that it can not only show the blood was not Castro's but prove it was from his victims. A Frye test was used to determine the admissibility of the evidence in court, but because DNA fingerprinting is complex evidence that uses scientific procedures and analysis, a modified "three pronged" test was devised:

Prong 1: Is there a theory which is generally accepted in the scientific community, which supports the conclusion that DNA forensic testing can produce reliable results?

Prong 2: Are there techniques or experiments that currently exist that are capable of producing reliable results in DNA identification and are generally accepted in the scientific community?

Prong 3: Did the testing laboratory perform the accepted scientific techniques in analyzing the forensic samples in this particular case?

In this case, Lifecodes did not follow standard scientific procedures when analyzing this evidence, and thus it was not admitted. This case lead to the creation of the "Technical Working Group on DNA Analysis Methods" (TWGDAM) who established universal procedures for which DNA analysis must undergo. Castro ended up confessing to the murders (Patton, 1990, pg. 4).

United States vs. Two Bulls

In the case of United States v. Two Bulls, the court held an extended pre-trial hearing to address the admissibility of DNA evidence. This case also introduced the testing of admissibility of DNA profiling. The court was held under instruction to review the evidence under a new five pronged standard:

Prong 1: Is the DNA evidence generally accepted in the scientific community?

Prong 2: Are the testing procedures used generally accepted in as reliable if performed properly?

Prong 3: Was the test performed properly in this case?

Prong 4: Is the evidence more prejudicial than probative in this case?

Prong 5: Are the statistics used to determine the probability of someone else having the same characteristics more prejudicial than probative under Rule 403?

(Two Bulls v. United States, 1990; referenced in: Perry v. State. pg. 5).

Daubert v. Merrell Dow Pharmaceuticals

In 1993, one court case created a general standard for all scientific evidence, not just for DNA. The case of Daubert v. Merrell Dow Pharmaceuticals did not involve DNA itself, but it established a new five prong test that lead to a new standard in most cases after 1993. Jason Daubert was born with a birth defect of limb reduction and claimed that it was the result of his mother taking the morning sickness drug, Bendectin, during pregnancy. This case dealt with whether or not expert scientific testimony is admissible to prove that Bendictin caused the birth defects in the plaintiff.

Both the plaintiff and the defendant had expert scientific witnesses, the prosecution claiming Bendictin caused the defects, and the defense claiming Bendictin does not cause birth defects. The first debate was whether the expert testimony was based on scientific knowledge using the scientific method to get results. The plaintiff's claim was not supported by any statistical or published theory, only tests based on in vitro non-human testing. The second debate was whether the testimony was relevant to the case. The plaintiff's expert testimony was given by scientists who were hired only for the case. They had no prior research of this claim before the trial. The testimony was based on the possibility that the cause of the defects were from the drug, not probability. The testimony was deemed not admissible in court (Green et al., 1993; 1995).

After the trial, a new set of standards were made for the admissibility of all scientific evidence. This new five prong standard was used in many cases following the 1993 case. The new standards use five validations, but is more flexible stating that these are guidelines rather than a checklist. The five prongs are:

Prong 1: Proof of testing of the basic underlying hypothesis upon which the technique rests.

Prong 2: Peer review and publications.

Prong 3: A known or potential error rate.

Prong 4: The existence of an accepted methodology.

Prong 5: General acceptance of a technique in the forensic community.

The first prong needs to show there is research and examinations of the proposed technique being explored. Also that there is no research denying the existence of the skills used in the technique. The second prong shows that there are findings or research in peer-reviewed scientific and technical journals and other documentation. The third prong shows that even if there are no quantitative results there is a general degree to which something can be proven based on an expert's opinion with a reasonable degree of scientific, professional or medical certainty. The fourth prong shows that methodologies used for the proposed techniques have been tested and used, and that the tests were designed with a neutral viewpoint, not having a preconceived notion of what the outcome should be. The fifth prong shows that there is a general acceptance of the skills in the forensic science profession and scientific community (Moenssens, 1999).

DNA Warrant: People vs. Paul Eugene Robinson

By 1994, DNA had taken an amazing turn in the court room, many courts allowed DNA evidence. One of the most amazing DNA cases proving how useful DNA identification and profiling is the case of a 1994 Sacramento rape. There was no real information about the person suspected of the rape, only that his DNA was left at the scene. With no suspects the case went cold, and as the statute of limitations approached for the case, the police put out a "John Doe" warrant using only the genetic code as a distinguishing marker. Unfortunately the warrant was under scrutiny because the genetic code did not fit the format required for a legal warrant and the actual warrant stated only "John Doe", black male. Because there was no format fitting for this type of identification and the genetic code was immediately accessible, this warrant was allowed.

THE PEOPLE OF THE STATE OF CALIFORNIA,

vs.

JOHN DOE ,unknown male with Short Tandem Repeat (STR) Deoxyribonucleic Acid (DNA) Profile at the following Genetic Locations, using the COfiler and Profiler Plus Polymerase Chain Reaction (PCR) amplifications kits: D3S1358 (15,15), D16S539 (9,10), THO1(7,7), TPOX (6,9), CSF1PO (10,11), D7S820 (8,11), vWa (18,19), FGA (22,24), D8S1179 (12,15), D21S11 (28,28), D18S51 (20,20), D5S818 (8,13), D13S317 (10,11), with said Genetic Profile being unique, occurring in approximately 1 in 21 sextillion of the Caucasian population, 1 in 650 quadrillion of the African American population, 1in 420 sextillion of the Hispanic population

Figure-29. DNA Code "John Doe" Warrant . Delsohn. Cracking an Unsolved...(2001).

Figure-30. Paul Eugene Robinson. Delsohn.Cracking an Unsolved... (2001).

This John Doe warrant was put into a database and police hoped for the best. Paul Eugene Robinson was arrested in 1998 for violating his parole while he was caught prowling on private property. The jailers checked his criminal history and mistakenly took his DNA sample based on a spouse abuse conviction. Because this was only a misdemeanor and not a felony, it was normally not to be collected. However, this DNA matched the DNA in the database for the John Doe rape warrant. Although accidental, it was allowed in court and Robinson was charged based on the evidence (Delsohn. Cracking an Unsolved Rape Case. 2001).

Chapter-4: Sensational DNA Media Cases

As of 1996, 46 states admitted DNA evidence in the courtroom, with Maine, Rhode Island, Utah and North Dakota being the only four that did not. Three states, Tennessee, Nevada and Oklahoma, have statutes requiring admission, but these figures are dependent on the laboratories ability to perform the tests properly and use standard controls in the experiments. With standard DNA testing procedures now in place, and legal precedents already set for allowing this type of complex testing into the courtroom, we now direct our attention to a discussion of several U.S. court cases involving DNA that the public is likely familiar with to show the power of DNA evidence.

Now that DNA is widely accepted it has been one of the best means for convicting a person with no doubt. The statistics prove that the probability of two individuals having the same genetic characteristics at the standard 13 core loci are less than one in a trillion. This has been a driving principle in the identification of criminals, and cases involving DNA evidence have hit the media.

The O.J. Simpson Case

One of the best known and controversial cases involving DNA was the 1994 murder trial of Orenthal James Simpson (age 46). The O.J. Simpson trial, commonly known as the trial of the century, was the longest time a jury had been sequestered, with 266 days spent examining the testimony of over 124 experts and witnesses and 488 exhibits (Lee, 2003, pg. 239).

On the night of June 12, 1994, O.J. Simpson's ex-wife, Nicole Brown Simpson, 35, and her male companion, Ronald Goldman, 25, were murdered in the Brentwood section of Los Angeles. One of the first and obvious issues of this case was race, O.J. was an African American man, and his ex-wife and Goldman were both Caucasian. One of the detectives in the case was also accused of racial discrimination which cast potential doubt as to the performance of the procedures used by the officers. Fame and public view was also another large and controversial issue in the case since O.J. Simpson was an evolving American hero. He was a star college football player, even started a small acting career and had become a well known and wealthy man.

Figure-31. O.J. Simpson.
http://en.epochtimes.com/news/7-9-14/59771.html

Figure-32. O.J. Simpson and Nicole Brown Simpson.
http://blog.canoe.ca/tanyaenberg/2006/11/16/the_juice_thickens

Figure-33.Ronald Goldman.

http://www.usatoday.com/news/index/nns9.htm

On the night of the murder, Steven Schwab, who lived three blocks away was taking his routine walk with his dog and was in an alley behind Nicole Simpson's home around 10:55 pm that night. There he found the family Akita dog, with what looked like blood on its paws, barking at the house. The Akita followed Schwab home and a friend of his joined Schwab and his wife to figure out what to do with this dog. Schwab's friend, Boztepe agreed to take the dog home with him, but the Akita was too nervous and when taken out for a walk, led Boztepe to Nicole's house. It was then that a woman was found lying in a pool of blood on the walkway. Boztepe knocked frantically on a neighbor's door, raising concern from the neighbor who was frightened that she might be attacked, and she called the police to check out the person outside her door. When the police arrived, everything was sorted out and the real danger, a brutal crime scene, was set to be investigated.

The officer responding, Robert Riske, approached 875 South Bundy surveying the scene. He discovered the body of Nicole Brown Simpson face down at the base of the stairs at the entrance of the home, in a pool of blood. She was stabbed and her head was almost severed off completely. Blood was also found all over the entry way tiles. Near by, a restaurant menu and another body, Ronald Goldman, with his shirt pulled up over his head, propped against a fence on the edge of the property, also stabbed, twenty eight times. Near his body, a black ski cap, a white envelope, a pager, a torn piece of paper and a left hand leather glove were found. Riske moved his search to the hedges along the property and discovered a passage that led to the back alley. There he found a set of bloody shoe prints and a trail of blood droplets.

Figure-34. Bundy Entrance and Nicole's Body . *http://womensspace.wordpress.com/2006/11/15/todays-male-terrorism-oj-simpson-to-tell-how-he-would-have-killed-nicole-brown-simpson/*

Figure-35. Bloody Glove Evidence . *http://espn.go.com/page2/s/wiley/021113.html*

Riske made his way to the front door, which was open, and entered seeing no signs of struggle or forced entry. Candles were lit in the living room, master bedroom and bathroom, the tub filled with water. Two sleeping children were found in their beds upstairs. In the foyer, a letter sent by O.J. Simpson was left on a table, and pictures of him were also noted throughout other rooms in the house. When police back up arrived, detective Vannatter took over, and a more through search provided blood smears on the gate at the back alleyway, ice cream melting in the back of the house, and more bloodstains.

The investigation led the detectives to Simpson's home where a Ford Bronco was found to have what appeared to be blood smears. The detectives went into the house without a search warrant, using the circumstance of a possible emergency. Simpson's house guest, Kato Kaelin was interviewed about anything unusual that had happened the night of the murder and he replied yes. He described loud thumps on his bedroom wall near the street. A path was discovered behind the wall described, and when they followed that path a bloody right hand glove, similar to the glove at the Bundy scene was recovered. Simpson had a history of spousal abuse and when his ex-wife was found murdered, he immediately became the prime suspect.

Simpson had left the night of the murder, the twelfth, for the airport. A limo driver, Allen Park, was to arrive at his house around 10:45 pm and be to the airport by 11:45 pm. The driver showed up about twenty minutes early and described the evening's time line. He did not see the Bronco parked on the street when he arrived and at 10:40 pm, he rang the bell at Simpson's front gate receiving no response. Park called his boss on his cell phone worried that he was losing time to get Simpson to the airport in time. Other phone calls were made establishing a call history that was helpful to the time line. Park stated he saw a man (later determined to be Kaelin) exit the back of the house and disappear into it again. Just after, an African American man, roughly six feet tall, two hundred pounds was seen entering the front of the house and lights began to turn on. Park rang the bell again and Simpson answered, saying he overslept and would be down shortly. Simpson and Kaelin emerged from the house and loaded suitcases into the limo. When Park left just around eleven, he noticed something obstructing his view at the curb, but could not identify it as the Bronco.

Simpson was arrested on June 17th, and a blood sample was taken. The blood was not properly stored, but instead, placed inside detective Vannatter's pants pocket and brought to an investigator at the Bundy scene, placed in a van until later that evening and then finally taken to the lab to be properly stored. This was a serious mistake. Possible deterioration, contamination and mishandling could have occurred, as well as chain of custody issues of the evidence. Blood tests determined that blood from the Bundy pathway was found to match Simpson's, with only seven percent of the population that could have possibly left those blood traces. The blood found on the glove was a combination of O.J. Simpson, Nicole Simpson and Ron Goldman's. These tests were unfortunately compared to the blood sample taken from O.J. Simpson that could have been no good.

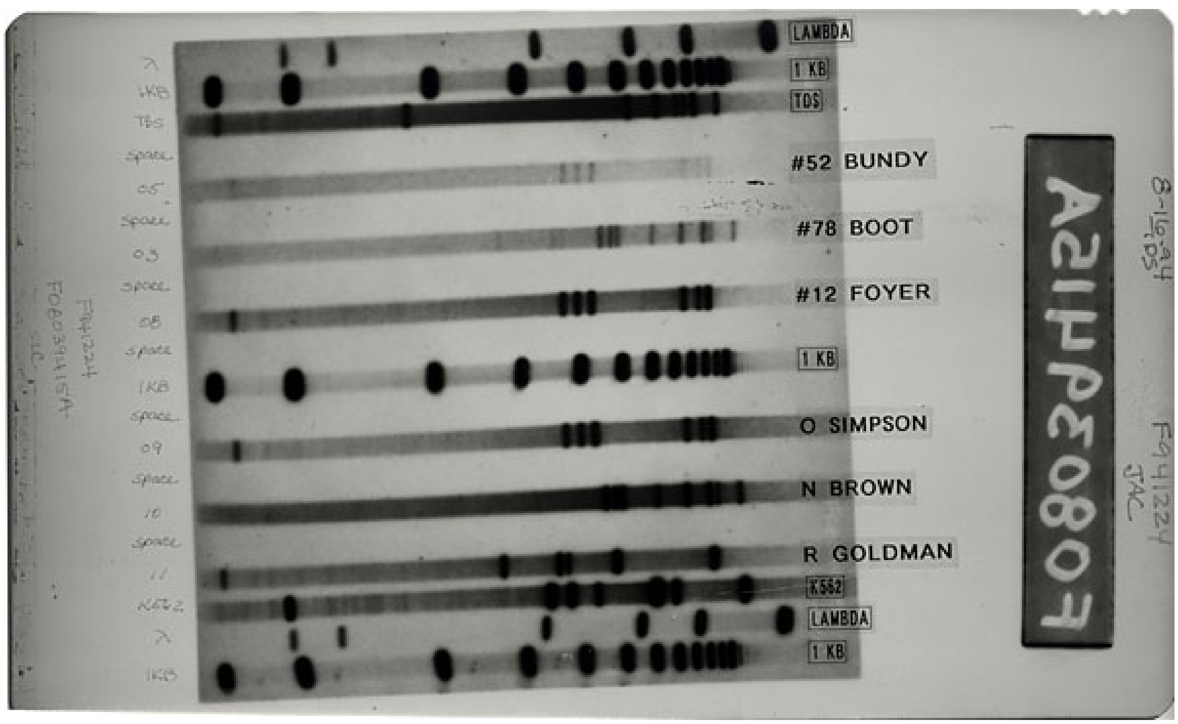


Figure-36. OJ Trial Blood Evidence DNA Fingerprint.
http://www.nmnh.si.edu/naa/whatsnew2002_08.htm

Other issues involved police and forensic technicians walking through the scene unprotected, and possibly cleaning up blood evidence to get to the bodies faster, and depositing other bloody garments on the body of Goldman. While searching Simpson's house, evidence of bloody socks were not properly photographed before being collected, nor was there any proper record of this evidence in the initial walk through notes. Some blood evidence such as gravitational blood droplets on Nicole's back was ignored. Video evidence of one investigator revealed her dropping cotton swabs, cleaning instruments with dirty gloves on, and using the same swab for different pieces of evidence. Other evidence collectors were found to not use gloves throughout all collection, using plastic bags instead of paper evidence bags to for collection, and placing a blanket from inside the victim's house over her body. Simpson's blood sample was also admitted to have been spilled and not cleaned up properly or in a timely fashion, possibly contaminating other evidence nearby.

It was also suggested that evidence, such as the gloves and blood, could have been planted at the scenes to implicate O.J. Simpson. Stains in the Bronco placed Goldman inside the vehicle or placed Simpson at the crime scene. But a lot of blood evidence seemed to just 'turn up' at second visits to the Bronco or houses. The defense set off with a theory that several investigators conspired together to set up Simpson. In that direction, one of those detectives when prompted for a fictitious screen play of LAPD life was recorded speaking about how to place evidence at a crime scene, and how to implicate possible theories.

The prosecution brought forth 45 different bloodstains tested by three independent laboratories. Even with the contamination problem, the prosecution still pushed forth showing that blood DNA leading away from the Bundy scene matched O.J.'s, and that degradation could only eliminate the possibilities of matches, but not change the DNA profile into another. Although those stains were degraded and provided poor statistical results, there was enough blood in the last drop to show that the probability of a random match (other than O.J. Simpson) was one in 170 million.

Simpson was also found to have a cut on his finger, placing blood in the Bronco and possibly on the gloves. At the trial, however, Simpson tried on the gloves, arguing they were too small. They eventually "fit" but not without some effort noted on Simpson's face while pulling them on. Other tests and videos were used to disprove the theory of the misfit gloves, for example the gloves were damp, shrinking the fabric. Blood in the Bronco was also collected in two waves, one being after it was released to an unsecured lot, and the other after a report of it being burglarized. The bloody shoe prints proved to be another problem. They were discovered to be made only by size 12 Bruno Magli Italian designer shoes, but there was no way at this time to link O.J. to those shoes, the prosecution could not prove that he had ever owned a pair (photos of him wearing a similar pair of shoes was later uncovered for the civil trial).

Figure-37. Simpson Trial Misfit Gloves.
http://www.austin360.com/tv/content/tv/stories/2006/11/NYET130_SIMPSON_INTERVIEW_SIM.html

Overall, the blood evidence handling and investigative procedures were not up to standard and thus not valid. O.J. Simpson was acquitted in his criminal trial, and it only took the jury four hours to come to that verdict. There were just too many inconsistencies, unknowns and mistakes made involving this case (Lee, 2003, pg. 239-289; Lee, 2002, pg. 157-229). Simpson was later convicted in a civil case of wrongful death, where a case is established based on the preponderance of the evidence, instead of without a doubt in criminal trials. Some evidence in this case were the photographs of him wearing the same type of shoes that were found to leave the bloody prints in the murder trial. He was found guilty of wrongfully causing the death of Nicole Simpson and Ron Goldman (Linder, 2000).

Although the OJ Simpson case is probably the most well known DNA evidence case, DNA has also brought some closure to older cases that also hit the media. Recently cases such as the JonBenet Ramsey case, the Dr. Sam Shepard case, and the Boston Strangler case have had new evidence added, even decades after the crimes were committed. These cases ran cold or had been closed, but new DNA evidence has been brought forth for testing in the hope of finding the accused innocent or finding the murderer once and for all.

The Boston Strangler

Between June 14, 1962 and January 4, 1964, thirteen women, all single and ranging from age 19 to 85, were murdered. Eleven of the thirteen murders seemed to be connected as a string of serial murders in the Boston Massachusetts area, giving the murderer the title of the Boston Strangler. All the women were sexually molested and strangled with an article of their own clothing in their apartments. There was no sign of forced entry to any of the buildings, indicating that the killer was let into the apartments. This eventually lead investigators to find how this man was able to get into all these women's apartments.

A few years prior to the murders in Boston, a man was knocking on apartment doors posing as a modeling agent. If a female answered he would tell them that they were being scouted as a model. He explained that the company was respectable and that if interested he would take some measurements and they would receive a call later. A number of women let him in and measure them, he was a charming man in his twenties and seemed nice and respectable. No call from this 'agency' was ever received and a few suspicious women called the police about the incident. This stranger was given the name “the measuring man”.

In 1961 a man was caught entering a house. He confessed to the crime and also confessed to being the so called “Measuring Man”. His real name was Albert DeSalvo, a 29 year old family man with a decent job, but whom had a record of breaking and entering and stealing money.

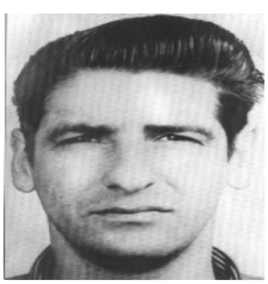


Figure-38. Albert DeSalvo.
http://www.macalester.edu/psychology/whathap/UBNRP/serialkillers/boston_strangler.html

When DeSalvo was a child, he lived with a violent father who abused his wife and kids. This household atmosphere lead to his criminal delinquency as a young man. He met his wife while stationed in Germany serving in the army. Shortly after, he and his wife had their first child, born with a severe physical handicap. Afraid of having another disabled child, his wife avoided sex. DeSalvo's sex drive on the other hand was very intense. When asked why he made up the “Measuring Man”, DeSalvo responded: “I was able to pull something over on high class people”. He received eighteen months in prison for the breaking and entering, but was released two months before the first murder for good behavior.

In late 1964, DeSalvo was again arrested. This time he sexually assaulted a young woman in her bedroom. He tied her to the bed with her clothes and held a knife to her throat. He asked her how to get out of the house, apologized and fled. The woman got a good look at the man's face and the police created a sketch with a resemblance to the Measuring Man. DeSalvo was brought in and identified by the woman through a one way mirror. He was released on bail, but his picture was released over the police network. Connecticut police were looking for a sexual predator called the Green Man. Police arrested DeSalvo at home, and his wife was not surprised and mentioned that Albert was addicted to sex. He admitted to entering over 400 apartments, assault of over 300 women and even rape; because he had a tendency to exaggerate, it was difficult to know exactly how many were true.

DeSalvo was admitted to Bridgewater State Hospital for observations where he became inmates with George Nassar who was convicted of executing a gas station attendant. Nassar's IQ was extremely high, and had the ability to manipulate people very well. DeSalvo and Nassar became close, disclosing many things to each other. In 1965 Albert had confessed to being the Boston Strangler. Dr. F. Lee Bailey interviewed

DeSalvo about the murders, hoping to discover something about the confession, whether it seemed that he was lying or recalling things from memory. Albert spoke with details such as the color of a rug, positions of furniture and described scenes unemotionally, as if describing images he had experienced.

DeSalvo described the details of every murder the strangler did. He even recalled an attack on a young female, to which he bailed on and begged the woman to not call the police. With only DeSalvo's story to go on the police tracked down the woman who remembered the incident. Police and Bailey came to the conclusion that Albert De Salvo was the Strangler.

Unfortunately there was no physical evidence to place DeSalvo at the scenes of any of the murders. The eyewitness who saw the strangler did not identify DeSalvo as the man seen at the scenes, however two eye witnesses who observed DeSalvo in a holding cell were startled, not by DeSalvo, but by his cell mate, Nassar. It is believed that DeSalvo confessed to the crimes to make money that could be used to support his family, and also the publicity would make him famous. DeSalvo had a very good memory and he could have memorized many things about each murder from the newspapers, layouts of apartments from burglaries he committed, or even from a source of information such as an inmate like Nassar.

One of the deceased victims, Mary Brown, raised some problems in linking DeSalvo to the murders. The details of this murder given by Albert were incorrect, possibly from a retelling of the murder from an inmate. The victim also lived near a victim of George Nassar. DeSalvo's confession was inadmissible as evidence but he was sentenced to life in prison for the Green Man assaults. While in prison, the night after

DeSalvo had phoned a Dr. Robey and a reporter to discuss the Boston Strangler, a knife was plunged into Albert's heart when he was in lock up in the infirmary (Bardsley and Bell, 2003).

Even though DeSalvo was never charged with the murders of those women, many people still consider him to be the Boston Strangler. Albert DeSalvo's brother, Richard, and a relative of Mary Sullivan, the Strangler's last victim wanted to prove DeSalvo wasn't the killer. Both Sullivan's and DeSalvo's remains were exhumed for DNA testing. A semen like substance on Sullivan's body was compared to the DNA of DeSalvo and was found to not be a match (BBC News, 2001). This new evidence does not disprove DeSalvo as being the Strangler, it does however prove that he did not sexually assault Sullivan. Even though this case was never officially closed, the new evidence leaves some possibility that the real Strangler is still out there somewhere.

"The Fugitive" Case: Dr. Sam Sheppard

The movie "The Fugitive" starring Harrison Ford is a popular spin on a big case, the case of Dr. Sam Sheppard and the murder of his wife Marilyn Sheppard. But there is much to the story than the movie portrays, many suspects and lots of evidence that was not considered.

Figure-39. "The Fugitive" Movie Poster.
http://www.impawards.com/1993/fugitive.html

The night of July 3, 1954, Marilyn and Sam Sheppard had entertained guests for the evening and everything seemed to have gone fine. Marilyn had gone upstairs to bed while Sam had fallen asleep downstairs on the day bed. He awoke to some sounds and raced upstairs where he saw a figure before he was knocked out.

Figure-40. Dr. Sam Sheppard. CNN US News (1998).
http://www.cnn.com/US/9803/05/sheppard.case/

Upon stirring, Sam saw his wife, brutally beaten, lying dead on the bed. Frantically, he checked for her pulse in a few areas, but found nothing, she was dead. Sam checked on his sleeping son in the next room, and in hearing rustling downstairs pursued a man he saw fleeing from his back door. He chased the man across the beach and had a struggle before he was again knocked unconscious. He came too and returned to his house, back to his wife's body, and after examining it again to prove she was really dead, phoned his neighbor, Mayor Houk. Houk and his wife Esther came right over. Mrs. Houk ran upstairs to find Marilyn's body as Mr. Houk called the police.

Sam had been injured and taken to the hospital. He sustained neck injuries and bruises that doctors said were legitimate and unlikely to be self inflicted. When questioned, Sam described a 'bushy-haired man' whom he grappled with before being knocked out. He also said that the man must have stolen his watch, class ring, keys and a few other things. The lack of blood and sand from the beach made this story seem very unlikely (McGunagle, 2004).

Sheppard denied cleaning up but there was no blood on his clothing or hands, and thus no blood transfer to the phone when he called his neighbor. The watch retrieved from a bag on the beach did have blood on it, but no sand. These inconsistencies made it difficult for the police to believe that Sheppard was in a struggle with the so- called burglar, which lead police to believe that Sam was the primary suspect (Crime Library, 2007).

Other suspects did emerge and other theories were developed. Besides Sheppard himself, the most known and suspected person involved was the window washer, Richard Eberling. He was familiar with the house, having washed windows there many times before, and he fit the description of the bushy-haired man. It was also discovered that a trail of blood on the stairs of the house was Eberling's blood type, and he admitted to cutting his hand at the Sheppard's house, however there was no evidence proving he was there the night of the murder. This evidence was tested after the trial once DNA testing became available, however it has a high possibility of contamination, because when it was collected back in 1954, the standards for collection and preservation did not include the possibility of DNA evidence. Eberling also made a “sort of” confession.

The other theory was that of the two Houk's killing Marilyn. It is suggested that Mr. Houk was having an affair with Marilyn, Mrs. Houk found out and killed her. There Mr. Houk came upon his wife and he took her side to help cover up the mess they made. It does however seem unlikely that Sheppard would not recognize his neighbor and friend. But, the claim of a sex crime does leave the possibility of an affair. Marilyn was found on her bed with her breasts and pubic area exposed, and a semen like substance was found not to be Sam's. This semen is said to match Eberling, however the validity of the evidence is highly questionable (McGunagle, 2004).

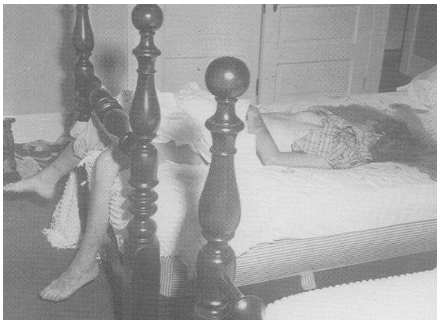


Figure-41. Marilyn's Body in Bed (Second Angle).
http://www.law.umkc.edu/faculty/projects/ftrials/sheppard/bodyofmarilyn2.jpg

Had DNA evidence been around when this case took place, it is very likely that the case would be closed. In 1966, Sam Shepard was found not guilty, however due to the evidence, the jury in 2002 ruled him not innocent.

The JonBenet Ramsey Case

DNA was not handled as well as it should have been in the cases we have discussed above, however DNA did help prove the innocence of the parent's of child pageant star, JonBenet Ramsey. On the night after Christmas in 1996, JonBenet was found in a small storage room in the basement of the Ramsey's Boulder Colorado home, and a ransom note written with a pad of paper and pen from the house was also found. She was wearing white long john pajamas and had what appears to be stun gun marks on her body. The crotch of her underwear was stained with blood and urine. Because of the note and handwriting samples from Patsy Ramsey, the mother, could not be ruled out, so the parents were the prime suspects.

Figure-42. Photo of JonBenet Ramsey.
http://www.cbc.ca/world/story/2006/08/16/jonbenet.html

Figure-43. John and Patsy Ramsey.
http://www.fresnobeehive.com/opinion/2006/08/

The theory that an intruder could have committed the crime was shot down and made more difficult to believe with all the pressure from the media. Many pieces of evidence however showed the likelihood of one or two murders from the outside. A window in the basement across the room where JonBenet was murdered was broken open, and had never been fixed by John Ramsey. This window was large enough for an adult male to slide through. Two different sized boot marks were also found in the basement. Upon the redirection of the case, looking at the blood evidence found in JonBenet's underwear, there was DNA of an unknown male mixed in. This piece of evidence created a full DNA profile that also matched a sample of skin found under her fingernails.

Now the police had a DNA profile but no suspects to match it to. They started taking a closer look at outside leads. A man named Helgoth was investigated. He owned a stun gun, talked about making a sizable amount of money, but became discouraged around Christmas time when none turned up, a boot print that matched the pattern found in the Ramsey's basement was taken into evidence, but the police stated they were the wrong size. Helgoth either committed suicide or was murdered by a gun shot wound, but one thing is for sure, the DNA did not match the DNA left on JonBenet.

Another man, who had stolen a candy cane decoration outside the Ramsey home was investigated. He owned a stun gun, was obsessed with serial killers, and also had a shrine of JonBenet on his computer. His DNA did not match the profile either. A sexual offender who lived down the street from the Ramsey's house was also tested, but no match was found (48 Hours, 2005; Justice Junctions, 2004).

The largest break in the case occurred in 2006 when John Mark Karr was arrested in Bangkok where he had received a teaching job. Investigators linked Karr to a series of contact attempts to Patsy Ramsey before her death. Karr admitted to being with JonBenet on the night of her death and that he drugged and sexual assaulted her. He admitted that he accidentally killed her and that strangulation lasted longer than he intended, causing severe damage, this lead him to strike her head. Karr was arrested and brought back to the United States for DNA testing. Unfortunately in October 2006, Karr's DNA test came back indicating he did not have sexual contact with JonBenet (USA Today, 2006).

Figure-44. John Mark Karr.
http://www.cbc.ca/world/story/2006/08/20/karr.html

People people involved in this investigation are divided on who they think did it. The Boulder DA has his own beliefs, and private investigators have theirs, both working towards the ultimate goal, to find JonBenet's killer. The real murder of this little girl is still out there, and just because investigators do not know a name, does not mean they don't have what is needed to eventually catch the killer or killers. Even though there are no suspects in this case, it doesn't mean it is over. The DNA sample they have has been stored for future use if there is another break in the case.

Chapter-5: DNA Databases, CODIS

DNA from crime scenes and from convicted people are stored in DNA databases. The largest known database for DNA is CODIS (Combined DNA Index System) run by the U.S. FBI for forensic use. It is similar to the fingerprint database known as AFIS; they are both electronic storages with information to identify people (National Institute of Justice, 1999, pg. 5). Although such databases have helped solve numerous crimes, ethical issues surround their use regarding who should be required to contribute DNA, and whether the included information could be misused in the future for medical information.

The CODIS database was started in 1990 and initially involved only 14 laboratories. The DNA Identification Act of 1994, "provided the statutory authority for creation of the National DNA Index System (NDIS) and specified the type of data that could be included in this national index. The types of DNA data that may be stored in the national index is administered by the FBI Director and consists of:

- DNA identification records of persons convicted of crimes;
- analyses of DNA samples recovered from crime scenes;
- analyses of DNA samples recovered from unidentified human remains; and
- analyses of DNA samples voluntarily contributed from relatives of missing persons.

(Adams, 2001).

In late 1998, NDIS became the first operational DNA database for law enforcement use. CODIS has now expanded throughout the 50 states and is comprised of three levels of association; the highest level is NDIS, allowing exchange and analysis of DNA in laboratories nationwide, followed by the state wide database SDIS, and finally the LDIS on the local level. These levels allow for specific control mandated by state and local laws (FBI, 2007b). Within the level of the database are two indexes: the forensic index and the offender index. The forensic index stores unknown DNA profiles recovered from crime scenes and the offender index stores DNA profiles of people convicted of sexual offenses, violent crimes and other felonies (FBI, 2007b).

As of 2006 the number of offender profiles in the database was 3,977,433 and the number of forensic profiles was 160,582. As of that same year, the number of offender hits made was 32,439, representing over 30,000 criminals who have been linked by DNA evidence, and allowing thousands of closed cases and getting dangerous people off the streets. The databases also contain missing persons reference profiles and DNA profiles from relatives, and even profiles of unidentified human remains. Not only are the databases being used to catch criminals, they are also used to help identify victims and other innocent people (FBI, 2007b).

All states participate in CODIS, however each state contributes in various degrees. Different states have different offenses that qualify to put the perpetrator's DNA into the system (see Figure-44).

STATE DNA DATABASE LAWS
QUALIFYING OFFENSES
(As of August 24, 2007)

	FELONY CONVICTIONS					MISDEMEANOR CONVICTIONS			ARRESTS			
STATE	All Convicted Felons	Juvenile Adjudications	Jail & Community Sentences	Retroactive Jail & Prison	Retroactive Probation & Parole	Certain Misde-meanors	Numerous Misde-Meanors	All Misde-meanors	Murder Arrestees	Sex Crimes Arrests	Burglary Arrests	All Felony Arrrests
ALABAMA	✓	✓	✓	✓	✓	✓						
ALASKA	✓	✓	✓	✓	✓	✓			✓	✓		
ARIZONA	✓	✓	✓	✓	✓	✓			✓	✓	✓	
ARKANSAS	✓		✓	✓		✓						
CALIFORNIA	✓	✓	✓	✓	✓	✓			✓	✓	✓*	✓*
COLORADO	✓	✓	✓	✓	✓	✓						
CONNECTICUT	✓		✓	✓	✓	✓						
DELAWARE	✓		✓			✓						
FLORIDA	✓	✓	✓	✓	✓	✓						
GEORGIA	✓	✓	✓			✓						
HAWAII	✓		✓	✓	✓	✓						
IDAHO			✓	✓	✓							
ILLINOIS	✓	✓	✓	✓		✓						
INDIANA	✓		✓	✓								
IOWA	✓	✓	✓	✓	✓	✓						
KANSAS	✓	✓	✓	✓	✓	✓			✓	✓	✓*	✓*
KENTUCKY		✓	✓									
LOUISIANA	✓	✓	✓	✓		✓			✓	✓	✓	✓
MAINE		✓	✓	✓								
MARYLAND	✓		✓	✓		✓						
MASSACHUSETTS	✓	✓	✓	✓	✓							
MICHIGAN	✓	✓	✓	✓		✓						
MINNESOTA	✓	✓	✓	✓		✓			✓	✓	✓	
MISSISSIPPI	✓		✓	✓								
MISSOURI	✓		✓	✓	✓	✓						
MONTANA	✓	✓	✓									
NEBRASKA			✓									
NEVADA	✓		✓			✓						
NEW HAMPSHIRE		✓	✓	✓	✓							
NEW JERSEY	✓	✓	✓	✓	✓	✓	✓					
NEW MEXICO	✓	✓	✓	✓	✓				✓	✓	✓	
NEW YORK	✓		✓	✓	✓	✓	✓					
NORTH CAROLINA	✓		✓	✓		✓						
NORTH DAKOTA	✓		✓	✓					✓*	✓*	✓*	✓*
OHIO	✓	✓	✓	✓	✓	✓						
OKLAHOMA	✓		✓	✓								
OREGON	✓	✓	✓	✓	✓	✓						
PENNSYLVANIA	✓	✓	✓	✓		✓						
RHODE ISLAND	✓		✓									
SOUTH CAROLINA	✓	✓	✓	✓	✓	✓						
SOUTH DAKOTA	✓	✓	✓	✓	✓	✓						
TENNESSEE	✓	✓	✓						✓	✓	✓	
TEXAS	✓	✓				✓			✓	✓	✓	
UTAH	✓	✓	✓	✓	✓	✓	✓					
VERMONT	✓		✓	✓	✓	✓						
VIRGINIA	✓	✓	✓	✓	✓				✓	✓		
WASHINGTON	✓	✓	✓	✓		✓						
WEST VIRGINIA	✓		✓			✓						
WISCONSIN	✓	✓	✓									
WYOMING	✓	✓	✓	✓	✓	✓						
	45	32	49	39	25	34	3	0	11	11	9	4

*States with delayed implementation dates for arrestee collection requirements.

(Figure-45. Chart of State DNA Database Qualifying Offenses. Honeywell. DNA Resources. 2007)

Most states require the majority of convicted felons to submit their DNA sample into CODIS, however in some states such as California, legislation has taken it so far as to submit DNA from all felony arrestees. However, some people believe this is going too far. What if charges are later dropped, the wrong person could be arrested, it is possible for innocent people to be forced to submit their personal DNA into a government database (American Civil Liberties Union, 2007).

Database Concerns

This is one of the concerns about databases, personal privacy. DNA not only contains genetic information about a person, but also the genetic information of any one closely related to them. Is it fair for investigators to use a family member's DNA to track down someone suspected of a crime? Police sometimes use “familial searches” to obtain partial matches that can lead them to the criminal (Genetics and Public Policy Center, 2007, pg 2-3). Other privacy concerns are that people who can browse the DNA have access to medical predisposition genetic information about a person. CODIS does not allow intrusion into the database, but certain state legislatures are not clear about who has access to this genetic information, and even if it is illegal to tap into the database, eventually someone will. Some states allow use of the criminal justice DNA data bank for non-forensic purposes. It is feared that the use of this information can be misused by research facilities, insurance purposes, employer's, and other unauthorized persons. It would be unfair for someone to use genetic information to exclude or discriminate against a person or persons (Etzioni, 2007, pgs. 18, 20; Genetics and Public Policy Center, 2007, pg. 3).

This issue leads in to the debate of who owns DNA? DNA comes from within our bodies, our blood, skin, saliva. Should someone be able to take our DNA and use it without our permission? What about the information found from the DNA sample itself? Unfortunately, there are very few laws that protect us against this. Once your DNA is in the database, it can be accessed and sent between states and persons anytime without our consent. However, we must also look at the common good in contrast to the personal privacy of individuals.

The Human Genome Project has already discovered many interesting and important factors and information about genetics and gene function. They are discovering more about people than most individuals have any clue about themselves. Most people do not know the benefits and possibilities that they house within their bodies. Genetic researchers and biotechnology companies can gain more information with the use of these DNA samples. The forensic use can hardly be contested, it is for the good of the public. People don't have control over the DNA they leave behind. Hair and saliva move about the air and are removed from our bodies, left out in public. Thus all our DNA can hardly be subjected to privacy laws.

I agree that possible misuse may come of these DNA samples and databases, however more good can come of it. If the protection of information was more tightly monitored, the needs of both the amazing abundance of uses and personal protection and privacy can be met. The information should not be used against them in a negative way, such as denial for insurance or a potential job, or other possible intrusions. Besides that factor of discrimination, what use do I have for the genetic codes in my body? I can't do anything with it, so why prevent the public good that can come of this research?

Another concern about privacy and misuse is the fact that DNA samples are not destroyed after they have served their purpose. Especially with forensics samples, as our DNA technology keeps improving, keeping the original source of the DNA is important. If a case goes cold or is closed, but for some reason needs to be reopened, it is important to have the original sample to be retested (ACLU, 2004). In the case of biotechnology resources, having the sample available for additional tests is important. If all that is recorded are the 13 core loci, less advancement can be made.

With the issue of testing all innocent people, for example requiring a blood sample from all newborns, and storing them in a database, is pushing it. The amount of money it would take to store all of those samples in a data base versus the use of the system does not convince me to move forward with this. Although it might help solve more crimes since even first time offenders could now be caught solely by their DNA evidence, most serious criminals are repeat offenders, so this percent gain might be small. For most people, they won't have any contact with forensic database information, and even if they do, and are cleared, probably won't again. The only reason I see for someone demanding their DNA be removed from the system once cleared, is a fear that it may lead to a connection in another crime or possible future crime.

As a typical person in the United States, many people have had access to my DNA. In donating blood, my normal activity, my genetic code has been viewed and shared by many individuals. I don't even have control over the DNA left behind everyday with hair and skin cells. Also, if my doctor ever found something in my blood that may be related to genetic disorders, or some other condition that may affect my health, I certainly would not mind if it was studied. Who knows the good that can come of it, and what help I may be able to receive? I would take those benefits over "genetic privacy" any day. I have no real use for my own genetic information, I am not a geneticist, they have more use for the code than I do.

It seems like most people are just unfamiliar with DNA and the systems that work with it. People are afraid of science and the advancements that can be made, and have already been made. The fear of less privacy and less personal control over themselves as individuals keep people against expanding DNA database technology. A lot of good has come from DNA and from research and use of databases, but people's fears cause doubt in CODIS and other related subjects. As long as proper restrictions and proper consequences for misuse of information is followed, these fears should fade over time. The government just needs to prove to people that this level of protection can be established and followed through.

CONCLUSIONS

DNA, the basis of all life, a microscopic ladder of genetic information has become a major force in society due to DNA testing. A lot of useful information and techniques have come from studying this fascinating material, and advances are continuing. DNA fingerprinting has a wide range of uses from determining the paternity of a child, finding a missing person, identifying human remains, to solving many crimes.

In early court cases involving DNA evidence, most were dismissed due a lack of clear precedence for accepting such complex information in court, or because the DNA sample was contaminated, degraded, or improperly controlled. New standards for collection and preservation of DNA evidence, and more accurate fingerprinting procedures, are helping advance DNA evidence in the courtroom. It has been shown that even when DNA evidence is admitted into court, it is not always a straightforward process. The landmark cases discussed in this IQP set original precedences for accepting this complex technological evidence in U.S. courts. Now DNA evidence is a widely accepted technology, as are DNA databases.

CODIS is the world's largest DNA database, consisting of DNA profiles of those convicted of violent felonies and misdemeanors. Ethical debates about genetic privacy and possible misuse of genetic information were discussed in this project. Although some people argue that contributing their DNA to these databases is a violation of privacy, research performed in this project shows that no medical information is contained in the forensic databases. Most state legislation agrees that there is great use in this technology and also contributes many samples to these databases, however there is still controversy over the legislation to destroy original samples due to potential benefits versus misuse of these samples. We conclude that DNA databases represent a powerful system to solve crimes, and agree with the current Massachusetts legislation requiring all convicted (but not arrested) felons and violent misdemeanors to provide DNA samples to the CODIS database. If you are convicted of a crime, you have lost some of your privacy rights. However, the addition of all persons DNA into a database is just not valid, and the possible benefits are minimal compared to the intrusion and the resources required to implement such a task.

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