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The Genome, Genetic Genealogy Database (3g Database)

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THE GENOME, GENETIC GENEALOGY DATABASE
(3G DATABASE)

BY

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BY

SALMA OBAID ALOTAIBI

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DEDICATION

To my longing and my love, despite the distance and its length...my dear homeland.

To the source of my strength and inspiration.... my beloved father.

To my happiness, comfort and reassurance... my virtuous mother.

To the one who had the first credit for granting me the honor of excellence and education, which we have not forgotten from our prayers always, King Abdullah bin Abdul Alaziz, may God have mercy on him.

To the generous and patient souls.... My dear husband and my beloved children.

To the owners of advice and souls who were generous with their support … my brothers, and sisters.

To those who sewed the path of success for me with their wise and guidance, the doctors and professors of my wonderful college.

To the great country from which I completed my distinction and began my launch, The United States.

To everyone who wished me well.

I dedicate to you my scientific thesis, which I hope will fly high to be a new station for combating crime and lifting injustice forever.

ABSTRACT

This is a qualitative research paper that used the content analysis method. Thirty-one sources which include journal articles, credible websites, and books were used to discuss the importance of having national and global genetic databases. DNA phenotyping is the technology used in criminal justice to identify crime suspects through observable traits in their DNA. This can play a key role in convicting the right crime perpetrators and avoiding future court appeals. It also helps during disaster recovery, where the victims are identified based on their DNA samples. Law enforcement agencies frequently use DNA to identify victims and solve high-profile cases such as murder. However, despite its success and usefulness in criminal justice, it faces some challenges. For example, there are often legislation limitations concerning access to and use of DNA evidence. In some countries, it is limited and can only be used for specific crimes; in others, it is widely used, but its use is limited in other ways, such as restrictions as evidence in court. It also faces ethical issues such as intentionally planting DNA samples or leaking sensitive information. Also, the public needs to fully support its use, even for low-profile cases. Despite these limitations, a universal DNA database would help reduce investigation costs and improve their effectiveness, sometimes even for property crimes. DNA is extremely useful due to its ability to solve complicated identity problems. An exemplary DNA database should contain DNA profiles for all citizens. Increasing the capacity of current databases, and connecting them to share information with authorized officials will help to create a robust DNA database for future generations.

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1.0 Introduction

Forensic Deoxyribonucleic Acid (DNA) phenotyping is one of the current technologies applicable in the criminal justice system in identifying crime suspects through observable characteristics (phenotype) from their DNA samples. The primary objective of DNA phenotyping is to help forensic officers identify unknown perpetrators through DNA evidence analysis collected from crime scene traces and presumed to be perpetrator's **(**Samuel & Prainsack, 2019**).** Despite its potential contribution to forensic investigation in criminal justice, forensic DNA phenotyping (FDP) is only regulated in two European countries. In the Netherlands, it is allowable to test for a person's sex, race, hair, and eye color. In Slovakia, the testing of visible DNA traits is permitted. However, in other European countries, application of forensic DNA phenotyping is complicated, or there are yet to be laws permitting its use in law enforcement agencies to solve crimes as primary evidence.

Lack of evidence has resulted in limitations in identifying criminal offenders from generation to generation. In some cases, there is insufficient evidence to arrest a perpetrator. Additionally, despite the forensic officers having DNA samples from the crime scene, they lack a reliable database to match it to identify an offender. This has resulted in delayed justice delivery due to the limitations caused by conventional forensic methods. The criminal investigation process is often complicated and has multiple steps which must be completed (Williams & Wienroth, 2017**)**. Investigation can take a long time, even years, to identify criminal perpetrators. Sometimes, the delay is not caused by a lack of evidence, but by not being able to properly apply technology to analyze the specimen from the crime scene.

The lack of a nationalized DNA database has given criminal offenders an advantage where they can escape the law. Criminal justice officials are continuously developing technology applications to help solve crimes. For instance, forensic investigation can use technology improvement to accurately and effectively identify criminals through DNA samples (Williams & Wienroth, 2017**).** The emergence of new technology can help minimize forensic officers' long process. Therefore, FDP should be implemented worldwide because of its significance and accuracy in identifying criminals within and outside the borders (Samuel & Prainsack, 2019). DNA registration should be done at birth and kept in each country's criminal justice department and the criminal justice department databases. This would play a key role in matching the DNA samples from the crime scene and identifying the perpetrator. Furthermore, it can be helpful in victim identification during the calamities such as floods and fires. The application of FDP will eradicate most cases registered under unknown offenders.

2.0 Methodology

For this study, content analysis was used to analyze thirty-one sources identified by a search for scholarly references about the topic that were published during the last ten years. The sources analyzed included scholarly journals, credible websites, and books that contain support and empirical examples that help explain why 3G Databases that emphasizes using FDP in the justice system should be implemented. The information from the articles and books will be used in the discussion and integrated into the analysis section. That will lead to meaningful recommendations and conclusions.

3.0 Background Information

3.1 Forensic DNA Phenotyping

The most notable aspect of applying forensic genetics is extracting DNA samples from evidence collected at a crime scene and comparing them with DNA profiles entered in FDP systems. DNA usage has gained popularity in the current era of technology (Machado & Silva, 2019). The evidence obtained from DNA is seen as solid and unquestionable before the forensic officers who use it to solve complex cases **(**Machado & Granja, 2020**).**

Despite its embracement in criminal justice investigation, it faces some drawbacks because no standard laws regulate its submission. Therefore, most individuals are not in the DNA database, which can be used as a matching system for the specimen obtained at the crime scene. Specimens include items such as, bloodstains, hair, and other materials containing DNA strands **(**Machado & Silva, 2019**)**. Studies have shown that DNA examination in criminal justice is crucial in identifying offenders, and the law should be implemented to create a national DNA storage database. A collective DNA storage system could quicken the investigation process, save valuable resources, and help the victim of the crime get justice more quickly **(**Machado & Granja, 2020**)**. The court data can show the ineffectiveness of traditional methods, while the US DNA systems can be used to show its relevance and cases where it is applicable.

The small size of DNA information in the database limits the performance of sensitive tests of statistical examinations of the markers for large scale. The testing of many individuals only happens when the investigators are given autonomy to store the individual DNA information in the systems. Some scholars have suggested that the DNA profiles in the FBI CODIS system should be made available for scientific study and testing. Instead of limiting its scope, all law enforcement agencies should use it for criminal identification. It should also include samples from both innocent and convicted individuals. Including only suspects' data limits the scope of identifying first-time criminals. The data should be kept indefinitely. The data should be kept indefinitely; it should not be deleted unless a victim or the perpetrator dies and the cases connected to them are all closed. This will increase the scope of the DNA database application and make it relevant in identifying criminals who will be verified using other methods to increase accuracy in prosecution (Thompson, 2013).

3.2 Factors Affecting Touch DNA

Touch DNA is the transfer of skin cells when a victim or object is touched. Numerous studies discuss touch DNA and its importance to criminal justice. DNA applies to sensitive cases such as sexual assaults, rapes, and murder. DNA genotyping has increased in recent years, and the current technology allows the extraction of DNA samples from touched items such as handbags, clothes, and jewelry (Alketbi, 2018). Technology has made it more straightforward to extract DNA from crime scenes and help the investigators identify the suspects based on the DNA test results. However, the quantity and quality of DNA deposited determine the credibility of the evidence. Some factors that can affect the DNA deposits include shedding status, the nature of the DNA deposits, and the deposition time and recovery time.

The shedding status plays a crucial role in DNA deposition. Several factors affect the shedding factors, for instance, the propensity of a person to shed the DNA, the activity involved in DNA deposition, and the contact quality during DNA deposition. People differ in their shedding patterns; some individuals shed skin cells more quickly than others. Another factor that will dictate the shedding difference is the person's habits. For instance, a person who touches their face often will shed more DNA profiles than those who do not. Additionally, the increased pressure between the surface and the skin will increase the possibility of DNA shedding (Alketbi, 2018).

Additionally, the surface where the DNA disposition is left dictates its durability. For example, a rough, porous surface, such as wood, has a higher chance of retaining DNA than smooth spaces like plastic surfaces. This is caused by the abrasive nature of the wood surface, which enables the dislodging of the cells leading to high chances of retention for a long time. The recovery of the cells from rough surfaces could be more effective than from smooth surfaces (Alketbi, 2018). The advantage of rough surfaces is that the DNA deposition is important because the amount recovered will typically be greater than those on smooth surfaces. However, this can be difficult where the cells' disposition on rough surfaces is slight. This means that forensic officers should focus more on the rough surfaces within the crime scene since the chances of finding DNA cells are higher than on smooth surfaces.

The time between DNA deposition (The time it was deposited by victim or perpetrator) and recovery is crucial in extracting the DNA cells from the crime scene. Other factors, such as the changing environment, could destroy DNA (Alketbi, 2018). Therefore, the condition of the surface at which the DNA cells are deposited plays a vital role in the period it will last. The shorter the recovery time, the lower the possibility of DNA contamination. Other factors which will affect DNA recovery are environmental factors which include temperature and humidity.

3.3 Forensic DNA Phenotyping Laws

One important use of the DNA database is expanding the international and national databases useful in criminal justice. It is possible that the genetic data collected from an individual could be stored in a centralized national system, which can be extracted and compared to the evidence collected from the crime scene. Instead of looking for suspects and collecting samples from their bodies, having the already functional DNA database could be easier than examining the other evidence collected. Despite the controversies associated with a national DNA database, there are almost 69 countries that have the system; however, it is estimated that only 39 countries have started integrating the process into the national criminal justice system (Machado & Granja, 2020).

Most of these countries are from Europe and North America; however, Asian countries are also considering applying these DNA database systems, for example, China and South Korea.

The development of DNA databases is consistent with the information society, which started in the 1980s. The maximum surveillance method will ensure that human data is in the national systems to identify crime perpetrators and victims quickly. Therefore, according to information society, a DNA database is economically, socially, and politically ethical and should be implemented. Forensic phenotyping technologies have yet to be recognized worldwide; however, they have been applied in many cases, especially in Europe. It was used in the Netherlands during the investigation of Marianne Vaatstra and in Spain after the Madrid train bombing for victim identification and the detection of Eva Blanco Puig's murderer. It was also used in German and Australia during the *Phantom of Heilbronn* case **(**Weinroth, 2018). It is also used across international borders to investigate organized crimes; for example, it is allowable in the *Prum Treaty* from the Council of the European Union (Weinroth, 2018). The technology has also been used to identify disaster victims across the states but is not harmonized across the jurisdiction. For example, in Germany, Canada, and Belgium, application of FDP is only for identification purposes and cannot be presented in court as evidence to convict the accused **(**Williams & Wienroth, 2017**)**. The technology can be extremely useful and can lead to policy changes; therefore, law enforcement agencies, policy makers, and forensic practitioners should lobby for applying FDP as a new and emerging technology in the criminal justice department and to be used in courts.

There is variation in the forensic databases and how they are organized and regulated at national and international levels. The national legislation explains when the DNA samples can be used or the reasons for the DNA databases based on criminal identification, scientific research, and civil identification. The limitations put in place by some statutory laws make it difficult to apply and implement DNA database for criminal identification (Machado & Granja, 2020). This is due to the restrictions to accessing the information stored in the DNA databases; for instance, in some countries, access is allowed only for scientists and not detectives. On the other hand, the information stored in the databases can only be communicated to certain people, which ensures confidentiality. If it is not communicated to the criminal justice officers, it is not applicable for the court proceedings, making it irrelevant in identifying the criminals or victims.

Even though some nations accept using DNA databases, they put limitations on criteria to insert and remove the genetics profiling and biological samples. Some aspects used to determine the extent of genetic profiling are the type of crime involved, the duration of imprisonment, the possibilities of reoffending, and the individual's behavioral characteristics. These factors put some limitations in establishing a robust, if fully functional, DNA database which could include the profiles of everyone in the country. It also controls the size of the DNA database, which limits its application scope. In Europe, two distinct countries are allowing DNA database profiling. Some have comprehensive legislation, while others have restrictive legislation. For example, the Netherlands, Hungary, Ireland, France, Spain, Germany, Ireland, and Belgium have restrictive legislation. On the other hand, Denmark, Scotland, Estonia, Australia, the United Kingdom, Finland, Latvia, and Lithuania have expansive legislation (Machado & Granja, 2020).

Countries with expansive legislation have fewer limitations on whose DNA to be included in the system. For example, DNA profiling could include individuals involved in any punishable court proceedings and individuals seen as suspects. On the other hand, the restrictive legislation include limiting the crimes and sentencing limits that qualify for suspect profiling, which should allow the authorities to insert an individual's DNA profile in the database (Machado & Granja, 2020). Therefore, it would be easier for the expansive countries to implement a full-scale functioning DNA database than the restrictive legislative countries. The data below shows the percentage proportion of individuals' total population in the respective countries' DNA databases.

Table 1: DNA Registration 2016

Country	**Population in Database in 2016**
Germany	1%
Austria	2.50%
Denmark	2.10%
France	5.00%
Netherlands	1.40%
Scotland	5.70%
Hungary	1.50%
England and Wales	8.80%
Sweden	1.50%

(Machado & Granja, 2020).

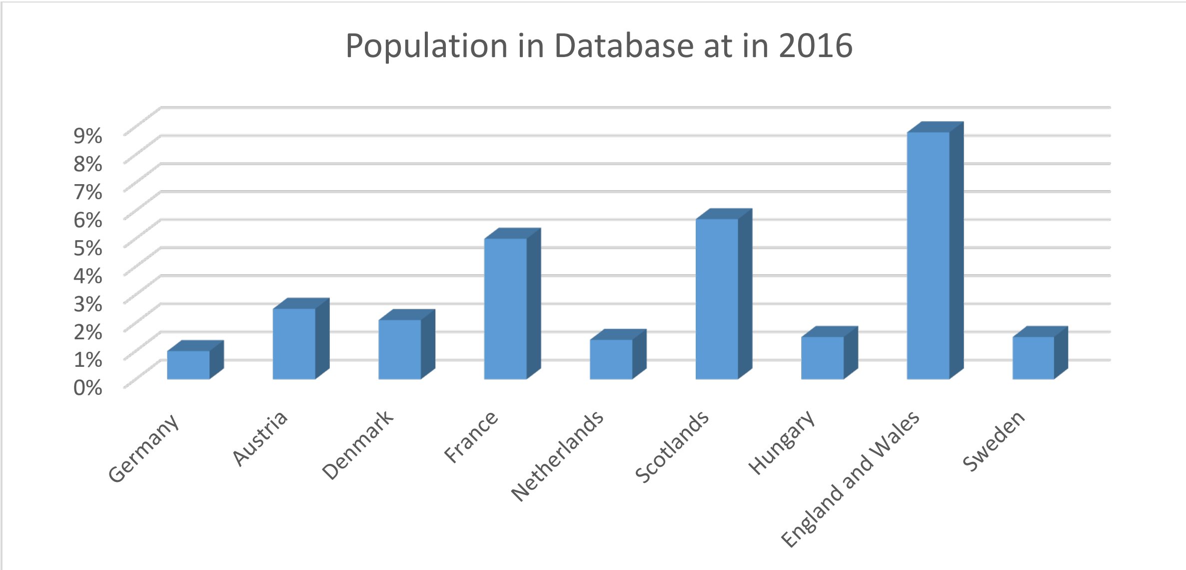

Figure 1: DNA Registration 2016 Summarizing Data from Table 1.

These data show the adoption of DNA databases in both restrictive and expanded countries. England and Wales have the highest database population compared to Germany. This is because England and Wales are both expansion countries while German is a restrictive country. On the other hand, the Netherlands, Sweden, and Hungary have a low population in the DNA database compared to Scotland and Austria. This is because Scotland and Austria are expansive legislation countries; on the other hand, Sweden, Netherlands, and Hungary are restrictive legislation countries. Therefore, from the above information is clear that the nature of legislation in the country limits or promotes the use of a DNA database.

4.0 Principle of Forensic DNA Phenotyping and Its Applicability

The United Kingdom is the leading user of DNA databases in the forensic field. Their system was implemented in 1988 to help resolve immigration problems. However, after using it for some period, they noticed that it is effective in much more expansive areas, especially in criminal investigations, due to the need for sample comparison. The DNA database was built to aid in identifying criminals. However, prior to 2001, it was only restricted to convicted individuals where the law advocated for records destruction for anybody who was not convicted. In 2000, Her Majesty's Inspectorate of Constabulary estimated that over 50,000 unlawful DNA profiles of non-convicted individuals were in the criminal database. This resulted in an amendment of the law to include the DNA profile of non-convicted people. Due to this amendment, England, Wales, and Ireland hand the most inclusive DNA database in the world. However, the legislature required the people to volunteer for inclusion, limiting the data collection. Over the years, the application of DNA databases in the United Kingdom has increased, and its effectiveness in criminal investigations has increased (Amorim & Budowle, 2016).

The primary principle of DNA is matching; without a forensic DNA database, the application of FDP is inapplicable. The database must have the donor's DNA, and as well as DNA from forensic crime profiles for effective identification **(**Amorim & Budowle, 2016**).** The biggest obstacle for FDP is that often there is no legal obligation to provide DNA samples; therefore, without the donor's stain in the database, there would be no match for the DNA evidence from the investigation. In short, the effectiveness of the FDP depends on the country’s law, where the convicted or suspected person is allowed or willing to provide their DNA stains to be included in the database.

Other types of DNA are those from dead victims and missing people where crimes are suspected. These inclusions are important because they may help solve unsolved cases and help identify previously unidentified bodies. This is achieved through matching with the victim’s DNA with their profile already in the DNA database. For instance, when a blood stain matching a person's DNA profile is found in a given place, forensic officers may be able to use it to help determine that person’s fate (Amorim & Budowle, 2016). However, this can happen long after additional legally bidding evidence is unavailable.

DNA matching can help identify the same person's crimes in different places and occasions. It can also help identify an individual who was never suspected or investigated for any crime, especially in more occurrence crimes such as car theft and burglary, which results in a considerable DNA profiling cluster**.** When the DNA of two people is found in the same crime, the investigators assume a relationship between the two people. When the DNA of either person is found in another crime with new DNA stains, forensic officers can connect the relationship between the offenders and crimes to understand their motive and their most possible plans (Amorim & Budowle, 2016). Therefore, FDP can be used as both a preventive and identification strategy.

The match rate is obtained by dividing the number of matches and the number of loaded individuals in the system. In December, the United Kingdom DNA database had 6 million subjects' profiles, and the crime profile match was approximately 600000. The match rate was highest in this period compared to previous years; for instance, in 2013-2014, it was 62%, while in 2017-2018, it was 66%. This shows that the DNA database is performed well in crime identification despite the reduced number of available records. Additionally, the crime rate reduced from 12.8% in 2016 to 11% in 2017. This shows that the system has a low influence on crime reduction but can be used to improve the justice system's performance. However, the matching is ineffective where the perpetrator or the victim's DNA samples are not in the database. Therefore, the offender's involvement will be established using other methods, such as CCTV cameras, fingerprints, or eyewitnesses (Amankwaa & McCartney, 2019). Additionally, some elements of duplications are due to mutations and identical twins. These issues may result in inefficiencies which will call for additional techniques to evaluate the effectiveness of the profiling. The DNA, despite having this limitation, can be used to minimize the resources used in an investigation by reducing the scope of victims' and perpetrators' identifications.

Although the application of DNA database is widely used in the USA, it is not used as primary evidence to convict an offender in most states. However, it can analyze crime statistics, clearance, prosecution efficiency, and cost-effectiveness. FBI Uniform Crime Report established that approximately 17.8% of serious crimes. 87.6% of crimes were property-related, and 12.4% were against the person. The clearance rate for the person-related cases using DNA testing was higher than property offenses. Part of this difference may be because the offenses against the person the perpetrator involve vigorous interaction with the offender and victim leaving DNA samples. However, in these cases, DNA analysis is only restricted to serious crimes such as violent and sexual abuse. This shows that DNA contributes little to resolving all crimes in the United States and only focuses on specific ones (Amankwaa & McCartney, 2019). It was also found that DNA is mainly used in populous areas despite many crimes committed in less populated areas, despite the many crimes committed in less populated areas. The application of DNA databases to cover all populations would be more cost-effective in the United States, and the use of law to restrict the sharing of DNA information to third parties not involved in crime-solving should be emphasized to increase its credibility and maintain high ethical standards.

In England, studies have shown that the use of DNA in solving property crimes was also low. One study used data from Pathfinder Project, which involved two police forces. Approximately 1.8 million property crimes are committed annually, and approximately 612,000 are assessed by crime scene detectives. Around 110 040 crime scenes visited yielded DNA samples, where the DNA profiling in these crime scenes yielded approximately 60% success

(Amankwaa & McCartney, 2019). However, fingerprints and DNA yield more results due to the database's absence of a DNA comparison profile. It was established that although DNA plays a crucial role in solving property crimes, its contribution to solving these crimes is lower than expected. However, the contribution of DNA evidence to solving murder cases is higher than for property crimes. Therefore, these findings are the same as those from the United States.

Results of existing research show that DNA analysis is most effective in solving murder cases. National governments should focus on first integrating legislation to allow DNA databases to be used in relation to homicide and other related crimes. DNA testing results should be validated using other methods, such as fingerprints or eyewitnesses. This will minimize the biological limitations related to it. Government should ensure that all citizens submit their DNA samples to relevant authorities. This will make matching more efficient, which is the core principle of the DNA database. Additionally, this will save the time and cost of looking for suspects and evaluating them through the elimination method. Through a robust system, it will be easier to identify the suspects and then use other methods to eliminate them.

5.0 Discussion

5.1 Courts Data

Appeals from criminal and civil court cases often show the submission of inadequate evidence in the court to convict and imprison the accused. In 2020, the United States Court of Appeals registered many appeals from civil and criminal cases. Appeals filings from twelve regional courts increased by 5%. There were 50,258 appeals for criminal cases and 27,500 from civil cases in 2020, and approximately 76% of the criminal appeals involved drugs, firearms, immigration, and property offenses (United States Courts, 2021). Some of these cases were overturned, at least in part, by lack of substantial evidence, which could have resulted in false imprisonment. Lack of evidence has also led to the dismissal of cases from lower courts.

The introduction of DNA comparing technology in England and Wales resulted in DNA profiling in criminal justice forensic investigations. Modern forensic geneticists have suggested that FDP in criminal justice has been successful in the conviction, exoneration, and identification of criminal suspects and victims (Weinroth, 2018). However, it is limited in the context where a similar profile cannot be matched or does not exist. Criminal justice experts suggest that FDP is a modern technology that can add more information in an investigation where they infer the physical appearance of the unknown suspect from their DNA (Williams & Wienroth, 2017). The invention of nucleotide polymorphisms has promoted the efficiency of FDP by discovering visible traits.

5.2 Law Enforcement

5.2.1 Reinforcing Physical Evidence

The only parameter considered in the courtroom during justice delivery is the law itself and the evidence presented in case. Sufficient and accurate evidence is critical in ensuring justice during prosecution of the perpetrator. Technology advancement has resulted in changes in evidence collection and processing. Although many issues related to evidence presentation, one controversial topic in the modern era is the DNA database. Forensic scientists and other concerned individuals advocate for its applicability and see its potential as the solution to current issues relating to criminal investigation (Machado & Granja, 2020). Unfortunately, in most states, the law does not allow it to be used in court as the primary source of evidence. Many considerations are implemented to ensure it is included as viable and source of valuable evidence in the courtroom. DNA processing and presentation in the courtroom is a procedure that ensures the accused suspect is almost certainly the one who committed the crime.

As mentioned previously, DNA evidence involves comparing the biological samples collected from crime scenes to the genetic profiles of an individual suspected to have committed or been associated with the crime. Some commonly used biological samples include hair, semen, skin, blood, sweat, saliva, and tears, all containing DNA (Machado & Granja, 2020). To complete the DNA analysis, the investigators should collect a sample from the identified person for comparison. This can be achieved through mouth smear, extracting blood samples, or collecting hair from the suspect. It can also involve scraping an individual's body parts to extract a person's skin sample for testing.

These samples are then taken to a forensic laboratory for testing. A biological technic called polymerase chain reaction is used to identify similarities between the DNA evidence and the sample from the suspect (Machado & Granja, 2020). It analyzes the DNA through replication in vitro and amplifies and analyzes DNA molecules. Although this method is allowed in most states, it is only helpful if the courts allow the evidence used to be utilized as primary evidence. Most prosecutors and detectives use it to eliminate the suspects from the list and narrow the scope of investigation by focusing on a few suspects. Of course, it is ineffective where no DNA samples can be compared with the evidence collected. Therefore, the need for a DNA database collection system would be helpful.

5.2.2 Solving Rape Cases

DNA testing has been used to solve cold cases; a good example is the Boston Strangler case. Mary Sullivan moved to Boston from Cape Cod when she was nineteen. Upon arrival, she rented an apartment in the Beacon Hill neighborhood. In January 1964, a few days after her relocation, she was found dead, and the leading cause of death was strangling and rape (Bulman, 2014). Unfortunately, she was one of eleven women Albert DeSalvo would confess to the killing. Although DeSalvo was sentenced to life for rape, he was never accused or convicted of any struggling case. In 1973, DeSalvo was stabbed to death by fellow inmates where he died. A decade after his death, the experts questioned whether DeSalvo was the strangler or someone who committed the crimes and escaped the law (Bulman, 2014). However, the evidence which connected DeSalvo to Sullivan's death was analyzed in July 2013.

From the DeSalvo case, it is clear that DNA can help to provide answers in complex cases. The National Institute of Justice funded the evaluation of cold cases in the USA to use DNA to solve these cases. The funding was crucial to the police department since it helped them to review investigate, and analyze the evidence (Bulman, 2014). Some of these cases were too old such that the DNA technology did not exist during their initial investigation; however, the biological evidence collected and stored could be used for the DNA match in current technology.

It was in 2009 and 2012 when Boston was granted National Institute of Justice (NIJ) funds to examine the cold cases. The Police Department in Boston decided to use the opportunity to examine the DeSalvo nephew's DNA and compare it to that collected from Sullivan's body and on the crime scene. When the DNA samples were run and compared, they gave positive results (Bulman, 2014). The DNA test used short tandem repeats (STRs) and DNA strand patterns. DNA experts utilize tests that focus on the Y-Chromosomes in the male body. This is because the Y-chromosomes are inherited from father to son, where the Y-STR DNA is passed across the generation to all male offspring (Bulman, 2014). By barring the mutation, the chromosomes never change; therefore, all the males in the lineage will have the same Y-STR DNA profile. This will include fathers, sons, brothers, cousins, grandsons, and nephews.

After testing Y-STRs from Sullivan's evidence, there was a match for DeSalvo's Nephew. From the evidence, the officials reported that the match was 99.9% true and that DeSalvo was the real strangler (Bulman, 2014). However, the Y-STR profile was the common thread in the family lineage, which did not give an exact answer to the question; the prosecutors could argue that the perpetrator of the crime was another family member, not DeSalvo.

From the match, the officials made another decision to test DeSalvo's DNA samples precisely. In 2013, they exhumed DeSalvo's body, focusing on conducting confirmatory tests using DNA tests directly. A DNA sample collected from the femur ad three teeth showed a match (Bulman, 2014). The DNA specialists calculated the possibility that it was another person who committed the crime. However, it was concluded with 99.9% certainty that DeSalvo committed the crime; that is, he raped and murdered Sullivan.

The case of Sullivan shows that DNA databases can play a crucial role in solving mysteries found in courts due to a lack of evidence. Through DNA tests, the police and investigators can quickly identify the crime perpetrator with certainty. This will help minimize the caseload and resources put into investigating crimes that can be solved through biological means. It will free resources for other responsibilities, such as funding the police or law enforcement officers' welfare. It will also help minimize the conviction of innocent people who are only convicted using other evidence, such as eyewitnesses, which could be caused by being in the wrong place at the wrong time. Therefore, the DNA database is vital to the law enforcement system and can be used to solve shortcomings faced in courts in today’s technology. However, other cases were solved through DNA evidence and can be used to reinforce the above conclusion.

5.2.3 Solving Murder Cases Which Cannot be Solved by Physical Evidence

Table 2: Cleared Cases from 2010 to 2022

	Year	**Cold Cases Cleared**
1	2010	8455
2	2011	8454
3	2012	8149
4	2013	8602
5	2014	8493
6	2015	9200
7	2016	9459
8	2017	9862
9	2018	9367
10	2019	8961
11	2020	10313
12	2021	7505

(Project: Cold Case, 2022)

From 2010 to 2022 the clearance of cold cases has increased tremendously. This is cause by application of DNA tests in identifying the suspects. From the table, in 2010, there were 8455 cold cases which were cleared. On other hand, in 2020, there were 10313 cases which were cleared. In 2021, the cases reduced since the government was focused on preventing COVID-19 prevention. Overall, application of technology in cold case clearance has been effective. The above information is presented in graph below:

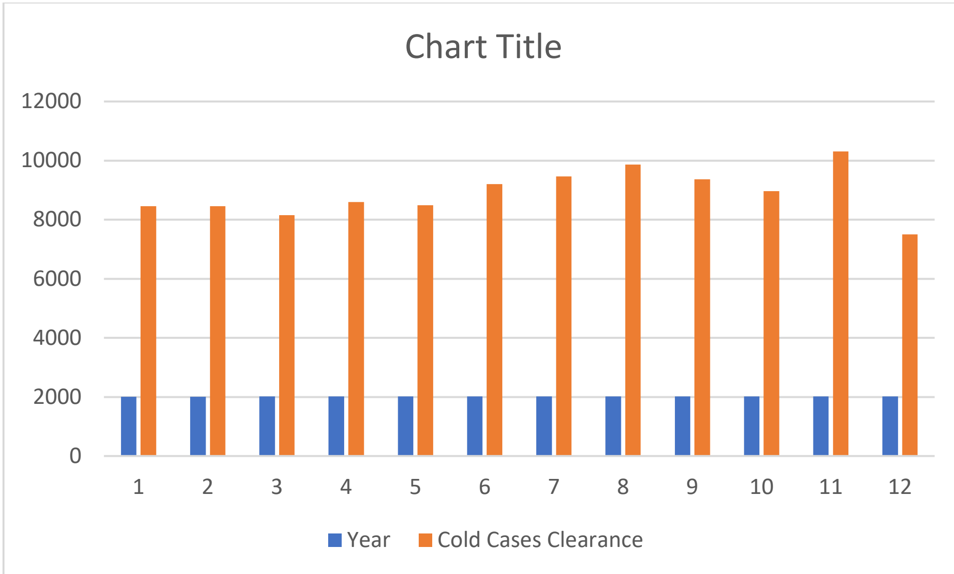

Figure 2: Graph Showing Cold Cases Cleared Between 2010 and 2021 Adapted from Project: Cold Case (2022).

As shown in the graph, 2020, which is year 11, had highest number of cleared cold cases. It was followed by year eight which is year 2017. The least year with cleared cold cases is 2021. This was due to COVID-19 effects. The government dedicated the resources to preventing COVID-19 impacts on economy. Some of the vital cold cases solved through DNA evidence are discussed below.

Shannon Lloyd of Orange County, California, was murdered in May 1987 when she was 23. According to the police department report, the leading cause of death was sexual assault and strangulation. In 1989, two years after Lloyd, Renee Cuevas was founded dead. The two cases were treated as unrelated till 2003 (Schwartz, 2023). National DNA database CODIS depicted that the collected samples from both crimes were related. They matched the same man; however, it was unfortunate since there was no match to compare. Therefore, the suspect was still unknown.

Then in 2021, the police officers tried generic genealogy, which utilizes unknown DNA samples and compares them with databases of the DNA to test partial but not exact matches. It is used to create a family tree through genetic similarities, which can lead to the owner of the sample under investigation. After the genetic genealogy, the results directed the officers to Rueben Smith. The police, through intensive investigation, realized that Smith was indeed in the area during the murders; he was convicted for crimes other than sexual assault or attempted murder (Schwartz, 2023). The DNA sample collected from the crime scene was used to convict Smith for the two cases, which are the murder and sexual assault of Lloyd and Cuevas.

Another case solved through DNA evidence was the gruesome double homicide in Great Falls, Montana, in 1955. Lloyd Bogle was shot dead when he was 18 years old. His belt was used to tie his hand behind the back. Patricia Kalitzke, his girlfriend, was also found dead the following day at another location. Both victims were shot in the head, but Kalitzke was sexually abused (Schwartz, 2023). Although the police determined that the case was related and after following many leads, it was unsuccessful.

In 2019, Detective JON Kadner issued the DNA samples collected from Kalitzke's sexual assault to the Bode Technology Genealogists. Using the reverse family tree technique, they used unknown DNA to search for matches from public databases. It led to Kenneth Gould, who died in 2007 (Schwartz, 2023). However, the scientists tested the DNA from the relatives of Gould, and with certainty, they concluded that he was the perpetrator of homicide and sexual assault.

In 1989, George and Catherine Peacock were killed. They were stabbed to death in their home, and there was no sign of forced entry. Michael Louise, the son-in-law of Peacock, was identified as the prime suspect, but the evidence against him was circumstantial; therefore, it could not connect Louise to the murders. However, in 2020, solid evidence was found, which was used to evaluate the case afresh. The police found a blood sample in Louise's car in 1989, and armed with that evidence; they decided to go for a DNA test. Since the initial blood test methods were inconclusive, the application of DNA testing would be helpful due to its advancement. The blood was tested and positively identified as George's. In 2022, Louise was convicted of a double homicide in 1989 (Schwartz, 2023). From this case, it is clear that a DNA database can be used to solve cold cases which happened decades ago, and the main suspects are still rooming in the streets. If it were not for the DNA test, Louise would still be free despite killing his in law in their homes.

Additionally, 32 years old Janet Love was raped and murdered in 1986 in her apartment in Bedford, Texas. The killer shot her in the head, and for 36 years, the case was transferred to different detectives, which none would solve. But in 2020, Sgt. Brett Bowen, an officer at Bedford Police, shared Love's DNA sample with forensic genealogy for testing. The DNA was matched to Ray Chapa, neighbor to Love, through a reverse family tree during her murder. Although Chapa died in 2021 before his identification, police officers are investigating if Chapa is connected to other murders in the area (Schwartz, 2023).

On the other hand, in 2002, Robert Reed was robbed and killed in his apartment. His neck and head had multiple injuries. All DNA tests only showed that the blood connected to the victim. However, in 2021 the case was revived. Sgt. Greg Harder from Elkhart County Police station noticed a piece of DNA evidence that was missed during a forensic investigation in 2002 (Schwartz, 2023). A blood spot on Reed's shirt indicated that the perpetrator stood on Reed's body while ransacking his pockets. After the DNA test, the blood was linked to Marcus Love. Based on the DNA test, Love was arrested for Reed's murder in 2022.

The case of Jessica Baggan was also solved through DNA testing. She was 17 when she was murdered and sexually assaulted in Sitka, Alaska. Since there was no physical evidence, the suspect was unknown, which made the case cold. However, in 2019, a DNA sample was collected from Baggen's clothes and then shared with public genealogists, where it was subjected to public genealogy database. Through DNA testing, for the first time, a suspect was identified. The DNA was linked to Steve Branch, where the troopers interviewed him concerning the murder. In 2020, he died from suicide, and during the autopsy, the DNA was confirmed to be a match (Schwartz, 2023). Therefore, Baggen's killer was Branch.

The case of Marise Chiverella, coded since 1964, was also solved through DNA testing. She was kidnapped in 1964 as she was walking to school. On the same day of the kidnap, Hazelton was also found dead after strangulation and raped. Over the years, the police officers worked on the case, but they could not find a lead. Then the case was revived in 2020 after implementing new DNA technology. Through DNA tests, James Forte, a convict of sexual assault, was identified as the perpetrator of both murders. Unfortunately, Forte died in 1980, and the DNA was collected from his exhumed body (Schwartz, 2023). Upon testing, it was found that his DNA matched that found on the victim's jacket, making him the killer.

Another case that was solved through DNA testing is that of Joette Smith. She was found floating on Lorenzo River, and the police suspected Eric Drummond, who had asked her for a date, but Smith declined his offer. This occurred five years after Smith's death, and the case turned cold due to a lack of physical evidence. However, in 2022, a DNA sample was found on Smith's clothes, and the new technology made it possible to collect the DNA and test it to find a match (Schwartz, 2023). After testing, the DNA results positively matched that of Drummond, and before he could be arrested and convicted for the murder of Smith, he committed suicide.

In 1980, Nadine Madger was also found dead in Willoughby, Ohio. She suffered 40 times stabbing; however, a blood sample other than that of Madger was found on her body, and it was suspected that the perpetrator remained unidentified. In 2022, the police used genealogical research to find the suspect (Schwartz, 2023). The DNA sample from blood found on Madger's body matched Stephen Simcack; unfortunately, Simcack died in 2018 and will not be convicted for murdering Madger.

Finally, in 1975, Lindy Beichler, who was 19 years found dead at her apartment in Lancaster, Pennsylvania. She was stabbed 19 times, and from the scene, the prosecutors argued that the evidence showed a sexual motive. Unfortunately, no substantial evidence was obtained to direct the officers toward the culprit. In 2019, the case was revived when the prosecutor provided the DNA samples left on the scene. Scientists applied DNA genealogy techniques using the public database to find a match. It directed the police officers to one of Beichler's neighbors during her murder. David Sinopoli was the suspect, and a direct DNA sample was obtained and matched to that collected at the crime scene, it matched (Schwartz, 2023). He was arrested in 2022 and will be convicted for the murder of Beichler.

These cases show that physical evidence is not the only option to convict criminals. Law enforcement agencies need more than just eyewitnesses or physical evidence. They need to embrace science and technology, including biological evidence, as a solution to complex cases. In this case, DNA phenotyping is the most effective solution to cases where the physical evidence is unreliable or inadequate (Schwartz, 2023). To make the DNA evidence more reliable and efficient, there is a need to implement an inclusive public database where each citizen's DNA strands are stored for matching in case of crimes. This will accelerate the case-finalizing process and make forensic officers' work easier. The collected DNA samples from crime scenes will be matched with those in the database, and the suspects will be easily identified (Schwartz, 2023). This will help in increasing the rate of crime as well as reducing the workload in courts. Unlike figure prints, the victim can collect the culprit's DNA samples, such as hair, body skin, or blood, during the crime to enable the forensic officers to identify them quickly. This will improve the efficiency and effectiveness of law enforcement agencies and reduce the cases of racial biases.

5.3 During Disasters

DNA generation from the skeletal remains has been crucial in identifying mass disasters and undefined victims. The problem with DNA is that it degrades immediately after a cell's death. Cell death through autolysis happens when they are no longer in contact with the body circulating oxygen caused by membrane rapture, realizing the enzymes that degrade the cellular structure**.** Therefore, the DNA degrades after contacting the enzymes due to chemical reactions that break or modify the DNA strands. This process takes a long time; therefore, analyzing the DNA in the bones and teeth can take much longer than in soft tissues. This is because the teeth and bones protect DNA molecules bound to the hydroxyapatite of complex tissues (Latham & Miller, 2019).

In the United States, DNA profiles generated from standardized nuclear and mtDNA analyses are used in DNA databases. It compares databases between the reference, crime scene, and unidentified person samples in different jurisdictions. This has promoted the implementation of genetic databases in different states, especially during disasters. In the United States, over 190 public laboratories are connected through the Combined DNA Index System (CODIS), where this system is distributed and managed by the FBI **(**Latham & Miller, 2019**).** The DNA is entered in different categories, such as unidentified human remains missing persons, relatives of missing persons, offenders, arrestees, detainees, and forensics. Then they are compared to identify any marches from the FDP database. The system is also organized according to the Local DNA Index System (LDIS), State DNA Index System (SDIS), and National DNA Index System (NDIS) levels **(**Latham & Miller, 2019**)**. The DNA provided by the families, usually taken victim's belongings, is used to identify them if a mass disaster happens.

Another widely used database in the USA is National Missing and Unidentified Person System (NamUs). It has non-genetic and genetic data of the missing person, unclaimed individuals, and unidentified decedents (Latham & Miller, 2019). Its effectiveness is based on accumulating data from a person, including documents, images, and body components (DNA), in one place. It is managed by the University of North Texas (UNT) Health Science Center with the help of the NIJ **(**Latham & Miller, 2019**)**. It is a storage place where the DNA results from disaster victims are kept for future reference and submits them to urgencies in need for free.

Other methods used in DNA identification during disasters include the short tandem repeats markers, single nucleotide polymorphism markers, and mitochondrial DNA. Since 1997, the FBI has been using 13 standard STR loci referred to as CODIS markers and sex-differentiating amelogenin locus. The Council European Union, through the European national DNA database, proposes using seven loci. These loci are used to increase the discrimination power between individuals to enable distinction for identification. Most STR markers are situated in different chromosomes, which have proven influential in most disaster fatalities. (Ziętkiewicz et al., 2012). However, it is only applicable where there are well-preserved soft tissues and bone samples, rendering it ineffective in some mass disasters.

The shortcomings of STR are solved using single nucleotide polymorphism markers (SNP). This is because they provide more human genome diversity compared to STR. For example, there could be over three million bases of distinction haploid genomes between two randomly chosen persons. It is commonly used in highly degraded remains without soft tissues or bones. For example, in a mass disaster where the fatalities are caused by burning, SNP is more effective than STR. It is also cost-effective and can be standardized due to its differentiating power, making it more useful in the criminal justice system (Ziętkiewicz et al., 2012). However, it possesses interpretation problems and needs to be analyzed by highly qualified forensic officials.

DNA genomes play a crucial role in the identification of the victims of fatalities during fatal disasters. This is because most of the victims are left unrecognizable during these disasters. This helps the family members know their members and care for their remains. It also helps the government identify the victims and the possibility of survivors (Ziętkiewicz et al., 2012). Some of the most disasters involving DNA use are airplane and water-related accidents. This is due to how many the victims' physical recognition features are destroyed during the accidents. DNA analysis makes identifying them by their names and kinship easier. Therefore, a universal database could be extremely useful in the current world.

5.3.1 Turkey Case Study

Turkey experienced a devastating earthquake that left a vast country in ruins. Days after the earthquake, thousands of bodies were to be identified. The earthquake in southern Turkey and northern Syria had already killed tens of thousands and injured thousands. As of February 17th, 2023, there were 44,000 deaths. At times, there were hundreds of corpses covered with body bags lying on the pavement, stadiums, or in hospitals (TRTWORLD and Agencies, 2023). Some had tags or identification documents that carried their names and the location of origin, making it easier to locate their relatives or at least place of origin. Unfortunately, some had no identification documents, and locating their families was impossible.

Those identified were given to their families, who were immediately issued death certificates and burial permits. This enabled them to take the bodies with local prosecutors' permission and bury them. The Disaster and Emergency Management Authority (AFAD) issued instructions to those not identified through public announcements. According to AFAD, unidentified bodies will be buried within 24 hours. This will occur after the collection of DNA and fingerprint samples. It was also stated that the provincial and district prosecutors' offices would examine and monitor the dead bodies from their location. They will not be moved to neighboring provinces or districts. Initially, it was stated that those not identified via forensic science and not delivered to their families or relatives would be buried within five days (TRTWORLD and Agencies, 2023). This would occur after the DNA tests, fingerprints, and photograph tests accompanied with the grave location written in official documents.

However, from the information obtained from affected religions, keeping the dead bodies for five days was impossible. The corpses were piling at high rates, and it was hard to preserve them due to the decomposition problem. This reduced the process to 24 hours which was inadequate to examine the bodies and compare them with the available DNA provided by the families which had lost their relatives (TRTWORLD and Agencies, 2023).

The Turkey case study is one of the real-life vents that call for implementing a national DNA database. It is the most effective method to solve such a natural disaster with a massive death toll. Unlike other identification methods, DNA samples can be extracted from any body part (Bowman et al., 2022). It can be extracted from the body remains after days of disaster where the bodies are not recognizable due to decomposition. This makes it more effective than other biometric recognition methods, such as fingerprints, face recognition, or eye recognition programs.

A Turkish national DNA database would have made it easier for the AFAD to identify the dead bodies within minimal time and send them to their relatives or families. Since the DNA of each of the victims is in a national database, the AFAD would collect the DNA samples from the victims and compare them to those in the system. Any matches would be recorded, and the relatives will be called for body collection (Bowman et al., 2022). This would simplify the process, and every family will have an opportunity to bury their family members with the dignity they deserve, per Turkish culture. Additionally, the government can account for every lost citizen during the earthquake.

However, in this case, the government might call off the search when other victims are still trapped underground. This could be due to public burial, which does not effectively allow the government to account for all bodies buried, especially where there is no DNA match to family members or the family members do not claim the bodies. Therefore, through the Turkey earthquake disaster, it is clear that a DNA database is crucial for any country and should be implemented. The government should advocate for mandatory DNA collection for all citizens to ensure attainment of matching principle. It should be integrated into the international DNA database since the victims are locals and comprise international visitors worldwide. Through awareness creation, the citizens will be able to understand the need for a massive DNA database and its benefit to them and society at large.

Although there are cases of unethical events that can take place by using information from a DNA database, there are some ways to mitigate them. Since the government currently keeps secretive documents from citizens which contain sensitive information, DNA information could have similar usage and access regulations. Technology can solve all these problems, although it poses threats. The information, like fingerprints and other identification details, can be kept in a national government database (Bowman et al., 2022). The system should be protected from third parties, and only authorized individuals can access it with permission from concerned authorities. Although there are some threats to keeping the DNA database, the benefits are more convincing.

From the Turkey case study, it is clear that, through the National DNA database, the government would have solved the issue of an identity crisis in many cases. They would hurry the identification process, and the families would be relieved to find their lost or affected relatives. On the other hand, the public resources would be released to solve other related issues brought labor by the disaster instead of allocating more resources to identification and burial. The families would absorb the burial costs while the government would focus on saving the victims or identifying dead bodies and sending them to the families for burial (Bowman et al., 2022). Therefore, this process would be faster, and most bodies would not be left identified, making them pile in hospitals, morgues, or fields. Therefore, the DNA database is the future.

5.4 Parental Issues

5.4.1 Missing Children and Mentally Challenged People

Approximately 73% of the people who go missing in the United States are children. Surprisingly, nine out of ten children who go missing run away. Other reasons for children going missing include stranger abductions, being thrown out by parents, family abductions, family misunderstandings, being injured, stranded, or lost. Since 1999 hundreds of children have gone missing without being found. The United States' reports are vast compared to other countries, such as the United Kingdom and Japan. In the United States, approximately 460,000 children are reported missing annually, where 99% return home safely, but one percent return home injured or does not return home at all. According to the recovery rate report, successful recovery rose to 97% in 2011 from 62% in 1990. The police report stated that one out of 10,000 missing children is either not found or is found dead. In 2011, the FBI reported that for every 40 seconds, a child goes missing in the United States (Dimetma, 2022). The report also showed the highest number of missing children was between twelve and seventeen. This shows that most of the children missing are running away or can run away. The table below shows the children who went missing in 2020 and their ages, as reported by the FBI database.

Table 3: Number of Children Went Missing in 2020

Number of Children Went Missing	Age Group
20 981	15-17
6 099	12-14
1 002	18-20
561	Below 2
394	9-11
391	3-5
301	6-8
53	Unknown

(Dimetma, 2022).

Table three shows that most children who went missing in 2020 were between 15 to 17 years. Most of the younger children below eight years rarely get lost. This shows that most children run away from their children, and abduction cases are minimal for younger children below eight. Most of those who run away from their homes are more likely to get stranded in the streets or get into criminal activities.

A universal DNA database could be imperative in some cases of missing children. Since the DNA samples can be tested to know kinship, it would be easier to test the children in the streets and connect them with their family members. It would also identify the runaway children who engaged in criminal activities and connect them to their parents or relatives while serving jail. A vast DNA system would be used for a criminal investigation to identify the parents of the children whose parents were stranded. This can be used to identify the father or mother of the child stranded in the streets and investigate the reasons for leaving the child because little children are left by their parents and end up in residential homes (Dimetma, 2022). The government could also use the DNA database to identify the family members willing to care for the child. This would not only reduce the cost of operation in residential homes but also help the child to grow in a conducive environment where they are cared for by their parents or family members.

5.4.2 Baby Swapping Case Study

There is no doubt that the most way to solve paternal cases is DNA testing. According to the latest studies, child swapping can have serious psychological problems for the mother and the child. Sometimes, the children are swapped by corrupt doctors or by mistake during birth. In such cases, the babies and their mothers are separated, and that case might not be solved using physical evidence (EasyDNA, 2014). Therefore, the only solution for child swapping is DNA testing. This will prove with certainty that the child belongs to a specific mother and not the other. The issue of Baby swapping is not new. In old biblical stories, two mothers fought for one baby before King Solomon. Although King Solomon used wisdom to solve the case, that only applies in some cases. This will call for the most effective methods to point out who is the mother of the child without a doubt. In this case, the DNA phenotype wins.

A Czech child-swapping case study indicates the need for DNA phenotyping. Two little girls were accidentally swapped during birth in Terbic Hospital in 2006. Nicole and Veronica had little time with their natural parents and were taken to cleaning by the staff, where they were later placed on maternity beds (EasyDNA, 2014). It was unclear how the swapping happened, but the girls were given to different parents.

The swapping mistake was recognized through distressing events where Nicole’s father accused his wife of cheating. Nicole had no resemblance to their family, which triggered the unfaithful allegations. Through secret DNA testing, it was revealed that he was not the natural father to Nicole (EasyDNA, 2014). This made him confront his wife, which made her desire to conduct a DNA test which found no match for both parents.

This made the parents call the hospital administration to inquire about where the mistake happened and how. Veronica's family was called through the elimination process, which was informed as a gross error. The two families were called, and when they met, every parent was given their children; the emotions ranged from extreme joy to sadness. They agreed to swap the children before their first birthday on December 9th (EasyDNA, 2014). They also agreed on regular visits to ease the trauma. The families decided to report the case to the court, where they will be compensated about ten million United States dollars.

From the case study, it is clear that child swapping cause psychological problems for children and parents. For instance, Nicole's father accused her wife of unfaithfulness in their marriage, which could have led to psychological problems. During the swapping, the parents and children felt anger and sadness. On the other hand, the hospital has to pay a fine of approximately ten million dollars for the damages they caused. To avoid all this, it is essential to use DNA phenotyping (EasyDNA, 2014). This will be the easiest way to ensure the child is given to the right parents. It will also help to ensure the child is given to a birth father and mother and not to any parent who claims to be theirs. Therefore, from the Czech case, it is clear that DNA phenotyping is crucial in solving parental cases.

5.5 Application to International Community

5.5.1 Preventing International Terrorism

DNA phenotyping is one of the crucial solutions to international security matters. Instead of multiple checks, the visitors could be identified through DNA comparisons as they try to enter a foreign country. This would minimize more paper works used while processing passports, such as physical identity files and cards that can also get lost. Each country encourage their citizens to submit their DNA samples to be integrated in national DNA database. It should be made mandatory that everyone share their DNA samples to relevant authorities to improve the effectiveness of DNA phenotyping system. This information should be connected to their fingerprint database. This will also be crucial in identifying those running from past crimes in their country of origin, such as political crimes, theft, rape, or kidnapping. Upon reaching the new country, after taking fingerprints or DNA tests, it will be identified if it matches any in international databases connected to criminal cases (Nybom et al., 2014). This will give vital information on whether the visitor has a criminal history or they have any pending court cases they are escaping from.

It will also help to put their DNA symbols in the system in case they do not exist to ensure they are traceable in case they commit crimes in a new country or in case their DNA samples emerge at crime scenes in the country of origin. For instance, if a person visits a country to further their studies or search for work and commits serious crimes where their DNA samples are obtained, they cannot escape since their DNA fingerprints are in the international system. For instance, the authorities solved cold cases after obtaining DNA samples from the suspects if the comparison DNA is in the system. In that case, it will be easier for law enforcement to identify the criminal culprits from foreign nations who only commit crimes and leave for their country to avoid arrest or suspicion (Nybom et al., 2014). This will enable law enforcement to prevent other crimes that the same person in different states might cause.

5.6 Benefits of DNA Phenotyping

DNA phenotyping can help in reducing the workload in law enforcement agencies. Anyone committing crimes will be identified if their DNA samples are collected from the crime scene and their profile is in the DNA database. It can accurately pinpoint the suspect, eliminating unnecessary procedures that police or investigators must follow that could produce evidence that might be circumstantial and ineffective in proving the suspect's involvement (Roewer, 2013). Additionally, it could be useful in solving other types of cases, such as complicated parental cases where the children are suspected of having been swapped.

A DNA database would also help law enforcement agencies and non-profit organizations focus on helping street children identify and reconnect with their families. This will help the children reconnect with their parents and families, improving their psychological, social, and physical development. DNA phenotyping is crucial in identifying otherwise unidentifiable persons. Additionally, it could possibly help deter crime since some potential offenders will be afraid of committing person-on-person crimes, such as rape, due to higher probability of being caught because of DNA samples (Roewer, 2013). Therefore, some crimes involving body contact or fluid exchange could be significantly reduced. Finally, it will help strengthen the state's system and preserve the security controls in the country.

6.0 Future Considerations

Forensic fields, including DNA analysis, will continue advancing, especially when identification of missing people, crime perpetrators, and victims of mass disasters are needed. The advancement and need for DNA analysis in the criminal justice department may reduce the limits imposed on DNA collection in some jurisdictions (Morrison et al., 2018). The government should consider mandatory DNA sample collection laws for the primary purpose of developing a larger database of profiles for comparison. Technological advancement, especially in biomedicine, will lead to improved DNA extraction methods that are fast and effective (Latham & Miller, 2019). Finally, the government should provide more funding and training to criminal justice department officers and forensic officials so that continuous research can be done on applying DNA knowledge in other aspects, such as predicting criminal behaviors.

The development of a more inclusive national DNA database could begin to make it worthwhile to collect samples for comparisons for non-violent crimes. A study to evaluate public opinion about the use of DNA in law enforcement found that the public supported its use in cases involving violent perpetrators, such as sexual assault and murder. They also supported its use to solve children-related cases such as missing people. However, the attitude toward its use in non-violent crimes was negative. For example, the public felt it should not be used in cases like drug abuse and car theft. These findings supported the idea that the majority supports the secondary use of DNA in solving high-profile cases, while its use in low-profile cases will not be supported by the public. However, in the future, DNA genotyping might be extended to be used in less violent crimes. This is due to its ability to reduce the investigation cost and minimize the investigation time. It would also be vital in solving serious immigration identification problems across borders. The current CODIS system could be more effective for kinship identification if there were fewer restrictions fir its use and if there were more profiles in the system (Katsanis, 2020). To maximize its use, there is a need to develop a diverse global DNA database that includes the profiles of every nation's citizens DNA samples obtained through volunteering. This will make the matching more accessible and effective since the needed comparison samples will readily be available for the forensic officers. Therefore, the amended law is needed to support the extension of the DNA database to cover all citizens.

Universal DNA databases should be considered in the future. The usefulness of the available data is determined by its accuracy in solving severe crimes. However, using a universal DNA database is challenged based on three main types of anonymity. Temporal anonymity is where a person can disappear, which is impossible in the current world where biometrics and fingerprints are used. The second type of anonymity is conduct which dictates what a person does at any given time. They argue that it is irrelevant to the criminal investigation, which is not the case. Finally, spatial anonymity explains where one visits. All these types of anonymity are crucial to active crime investigation. If the DNA database helps in solving them, then it will be easier to complete criminal investigations in a short time. This will reduce the time and cost of conducting a forensic investigation for high and low crimes. A universal DNA database will help solve cross-border crimes such as international terrorism (Katsanis, 2020). Tracking the perpetrators of the crimes hiding in foreign countries will be easier. Therefore, using a universal DNA database improves the effectiveness of international crime prevention strategies.

7.0 The Goal of Forensic DNA Phenotyping and Its Purpose

The main goal of DNA examination in criminal justice cases is to reduce the problems of identifying the victims and perpetrators. Suppose it is authorized, and a large number of DNA samples are obtained and registered in the national system, connected to an international profiling database. In that case, it will be easier to conduct a crime scene investigation and identify the perpetrators and victims through their belongings or body tissues. Collecting hereditary genes would not mean an individual is a criminal; it can be for their protection (Clayton et al., 2019). It is used in criminal contexts and in a disaster where the identification of victims remains is needed. Its benefits outweigh the disadvantages. Therefore, the government should request that citizens provide DNA samples by implementing the law to force those who resist. The effectiveness of examining hereditary genes can be explained through the 3G DataBase (The Genome, Genetic Genealogy Database).

The criminal officers get to the crime scene and look for the evidence which can lead them to any perpetrators. They examine everything suspicious in the crime scene, including figure prints and human remains. In the process, they find human remains, including sweat, hair, blood, and skin. After taking them to the laboratory, they process them to extract the DNA strands. Then they input the DNA sample into the database to see if there is any match. In this stage, they may find a match; if they fail, they can proceed to interrogation, which takes a long time before identifying the offenders (Clayton et al., 2019). This can lead to storing a corpse for a long time in case of murder until the lawsuit file is closed. Therefore, DNA examination with an adequate database can save time, resources, and psychological problems for both families, the accused, and forensic officers.

8.0 Criminological Theories Supporting Forensic DNA Phenotyping

Justice and equality are the core principle of ethical justice. All members of society should be treated the same by the law, and there should be no discrimination or unfairness. Therefore, the formation of social institutions to fight against crimes should be built under the virtues of justice and equality (Williams & Wienroth, 2017). According to criminological theories, the main question is: Will increased use of forensic DNA phenotyping lead to justice and equality? If it will result in apprehending criminals without affecting innocent individuals in society, it meets the basic criteria of fairness and equality.

Based on the cold cases solved through DNA testing supports the equality and justice theory of criminology. The main objective of this theory is to bring culprits to justice and convict them according to national criminal laws. DNA phenotyping has achieved that by helping convict the real culprits who had committed murder and rape assaults decades ago (Machado et al., 2020). This shows that the effectiveness of DNA phenotyping is higher compared to those of physical evidence. Where the physical evidence does not direct the investigators to the culprits, it is helpful to use a DNA sample collected at the crime scene to get them. Therefore, the implementation of a DNA database will be of great help to law enforcement agencies in delivering justice to all citizens in a shorter timeline.

Another theory that supports DNA phenotyping is biological theories of crimes, which call for a combination of criminology and biology. These types of theories focus on why some people engage in crime while others do not. What are the biological components present in criminals? They analyze criminals' physical, genetic, and neurological characteristics and compare them to those of regular citizens. They are divided into three main categories: identifying criminals based on their physical features, identifying criminals based on their genetics, and linking criminals based on their distinguishable characteristics from the body or brain (Burke, 2018). Based on biological theories, some of the causes of crimes among individuals is a genetic influence. This shows that some criminals have common genetic strands that are related to their propensities to engage in risk-taking behaviors such as crime. Using a DNA database, scientists can continue to explore this theory, and if correct, they can predict people with tendencies to commit crimes and the best ways to help them (Burke, 2018). This will be helpful to society, as long as this type of information is not used to discriminate against or label certain types of people based on their genetic strands.

Another criminological philosophy helpful in evaluating the effectiveness of Forensic DNA Phenotyping is retributive justice. It is also called corrective justice, which means righting wrongs through the criminal justice system. Applying DNA in the justice system will be helpful to the stakeholders, especially investigators and adjudicators. The patching of extensive criminal data with the collected sample will lead to criminal identification. Understanding the relationship between specific DNA genomes and criminal behaviors will be easier. For instance, it can be used to identify the genetic risk, that is, genetic preposition toward certain kinds of antisocial behaviors and violence. This information could be used not only in crime solving but also in crime prevention through programs that target first-time offenders at high risk for committing additional crimes. It could also be used to develop methods to treat criminals with a biological prosperity toward committing crimes (Williams & Wienroth, 2017). Through, Forensic DNA Phenotyping, law enforcement, with corroboration with healthcare professionals, will be able to prevent crimes in society, leading to reduced crimes.

Another philosophy that promotes the use of Forensic DNA Phenotyping is procedural justice. It is connected to the due process perspective that those involved in law enforcement are accorded their rights. It also ensures that the offenders are treated fairly. Due to Forensic DNA Phenotyping standardization and laboratory application, it will be easier to get consistent results, unlike other methods, which can be manipulated through human guesses. It can also be used to exonerate wrongly convicted people using questionable evidence. In case DNA samples were collected at the crime scene, the investigators, with the help of forensic scientists, can use them through matching to identify the real convicts and exonerate those convicted by using questionable evidence (Williams & Wienroth, 2017). Ensuring its accuracy can be combined with other evidence processing methods, strengthening the legal system procedures.

Distributive justice can be used to validate the use of Forensic DNA Phenotyping. It is the extent to which the benefits and burdens are shared amongst the community members. It can also be referred to as allocative justice. It advocates against the use of the common expression in the justice system, for instance, race, color, age, disability, or sexual orientation. It also ensures the suspects are given equal opportunity to exonerate themselves from the conviction if they are innocent. Although the police have been accused of unequal treatment where the black community is the primary victim, this can be solved through Forensic DNA Phenotyping (Williams & Wienroth, 2017). Unlike the current system, where the samples are collected and the suspects tested, the proposed system will compare the samples collected with the DNA database profiles. This will reduce the like hood of racial or social profiling. It will ensure all community members are treated the same, and the likelihood of having the right convict will be higher.

Information from the court cases where DNA testing was used to exonerate convicts supports the above theories. The first DNA exoneration took place in 1989; there are approximately 375 DNA exonerations in the United States. The average number of years served by the exonerated suspects was 14 years, and the average age of the wrongful convictions was around 26.6%, where the average age of exoneration was 43 years. Surprisingly, 21 of the 375 exonerated served death row, where 69% of the cases involved eyewitness misidentification. Approximately 165 actual assailants were identified and convicted. Of 375 people exonerated from the wrongful convictions, 225 were African American, 117 were Caucasian, 29 were Latin, two were Asian American, one was Native American, and one was self-identified (Innocence Project, n.d). From these statistics, it is clear that minority groups were the primary victims of wrongful convictions. Therefore, the use of DNA helped them from wrongful convictions.

9.0 When should Forensic DNA Phenotyping be Conducted?

If there is to eventually be a global DNA database that contains profiles of most individuals, the best time to collect the DNA for profiling would be at birth. The doctors and parents should collect and enter the children's DNA in the system as required (Robert & Dufresne, 2016). When a child is born outside hospital setting especially in the US rural areas and third world countries the parents should take the child for DNA profiling to ensure they are included in the DNA database. The DNA database should be connected to the national criminal justice department. Therefore, when the child's DNA is entered, it should be shared with other systems and stored for future reference. Those who provide their DNA for storage should register with their local government authorities, and the obtained samples should be sent to the centralized system for storage (Robert & Dufresne, 2016).

Since the FBI has been storing DNA samples successfully for the past decades, they are most qualified to collect the DNA samples of current generations and integrate them with the existing database. Like the fingerprints system, the DNA database usage scope should be extended to cover a wide range of investigations. The system should be integrated into the local authorities' systems to ensure they can use it in the investigations. Unlike the DNA database used by the FBI, doctors, and other healthcare authorities could use expanded DNA database to look for potential the health threats and the best ways to prevent and treat them. This will effectively reduce the cost of criminal investigation and improve generic-related research in the healthcare sector. However, the increased collection and analysis would come at a cost.

The first step to take is to enact a law allowing evidence from DNA databases to be used in courts. Any evidence obtained through DNA should be primary and authorized to apply. However, it should be used along with other evidence such as eye witnesses and fingerprints. The second issue is to create awareness and explain to the citizens the importance of using DNA in criminal investigations. This will help reduce social resistance, especially in its use in lower-profile cases. When people learn its importance, they will be more likely to support it, especially its ability to reduce crime rates. Finally, the government should establish a well-functional DNA collection system that does not make people anxious. It should be non-discriminatory, and all citizens should be treated the same. DNA should be the same as the election process, which is relatively repeatedly and thriving in the USA. This would be more effective if the citizens were encouraged to submit the samples voluntarily without being pushed.

10.0 Risks Associated with Forensic DNA Phenotyping

DNA profiling is one of the most controversial but crucial innovations in evidence collection. Most forensic investigators claim it is the most critical discovery in criminal justice and scholars have called it the most significant human discovery in forensic science. Due to its current considerations and controversies, it is crucial to identify the risks associated with FDP.

Since it is a new epistemology in forensic identification, there are claims that it is hard to achieve individualization; therefore, it should be based on probabilities rather than certainty. According to scientists, the ultimate call for DNA identification is individualization; however, it is not only affected by the identical twins' DNA similarities but also can be influenced by somatic mutations, which are intra-individual heterogeneity (Machado & Granja, 2020).

Another issue attached to DNA ineffectiveness is the contamination risk during crime scene collection and laboratory testing. It commonly happens in human remains, for example, in old and degraded samples such as mutilated bodies (Machado & Granja, 2020). This can result in false identification due to inadequate or degraded DNA collected. However, this can be minimized by integrating DNA evidence with other forms of evidence. The court should rely on more than one form of evidence but several. For example, the DNA sample can be used to narrow down the suspects, but the eyewitness and other evidence can further narrow the suspect lists until the criminals are caught.

The ethical issue associated with the information collected from DNA tests cannot be ignored. The conventional fingerprint method was only used for identification purposes but could not reveal serious information about the victim. DNA testing could reveal the individual's kinship, which is unknown to the person involved (Machado & Granja, 2020). It can also reveal the sensitive health issues in the person or the likelihood of an individual involving themselves in certain behaviors.

Unfortunately, the intentional planting of DNA raises some concerns. Criminals plan for the crimes and try to evade justice as hard as possible. Robust countermeasures follow any new method for catching criminals. For example, the history of safekeeping locks has been ineffective due to the criminals' methods of opening them (Thompson, 2013). In the case of DNA, it would be easier for criminals to diversify their tactics and plant misleading evidence. This will lower the crime-solving rates and increase the chances of false prosecutions (Thompson, 2013). Therefore, this will render DNA testing methods vulnerable, and law enforcement should have other evidence to back their claims.

Due to these limitations, it is crucial for law enforcement agencies to put in place some strategies to limit any controversies which could arise in the future. This should not include forensic scientists but the crime processing detectives, prosecutors, and judges. Forensic scientists should ensure that the testing materials can give certainties or that the risk of wrong identification is low and insignificant (Machado & Granja, 2020). It should also be integrated with other testing methods such as biometric identifications such as visual, fingerprints, and dental formulas. This will minimize the risk of unfair prosecutions and any DNA testing inconsistency.

The detectives and laboratory technicians should also ensure that crime processing and laboratory testing are conducive to DNA processing and testing. The possibility of sample contamination should be lower and insignificant. All professionals involved in evidence processing, testing, and presentation should have adequate knowledge of how to use it for the advantage of justice delivery (Machado & Granja, 2020). Some sensitive information from DNA testing should be kept confidential if they have no significant impact on the court or justice delivery. The risks associated with DNA profiling are manageable and should not limit its potential to solve current shortcomings in law enforcement.

11.0 Why Should DNA Submission Mandatory?

Development and maintenance of DNA databases should be under Clinical Laboratory Improvement Amendment (CLIA). It is a constitutional provision that provides guidelines and regulations governing the laboratory testing performed on humans across the US. Currently, it covers approximately 320 000 laboratories and is regulated by the Center for Medicare & Medicaid Services (CMS) (Evans, 2014). However, unlike other tests, the DNA database will primarily deter crime; therefore, it should be connected to the National Security Database controlled by the FBI.

The appropriate way to integrate it FBI database is through the extension of CODIS. CODIS is the current DNA database controlled by the FBI and only contains DNA samples from past and current convicts. Therefore, to protect personal privacy as time makes the DNA database functional and effective, it is advisable to integrate it into the CLIA regulations and CODIS database. This will ensure that the DNA information is kept private and only used by relevant law enforcement and clinical organizations.

On the other hand, the Constitution, through Fourth Amendment, provides provisions that protect citizens from unreasonable searches and seizures by the government. However, the Fourth Amendment does not guarantee against all kinds of search and seizure, but only those unreasonable before the Law. The Law allows the government to search any suspect given that they are executing legitimate government interests such as public safety (Etzioni, 2001). Implementing a DNA database should be mandatory since its primary objective is to improve public safety through the automated identification of victims and perpetrators.

DNA database is not the first security database that contains personal information. In 1999, the FBI implemented an International Automated Fingerprint Identification System (IAFIS), which is the largest collection of digital images of fingerprints of American citizens, features from fingerprint images, and any criminal history of the fingerprint owners (Stram et al., 2023). It further controls CODIS, a DNA database for criminals and convicts. This shows that the FBI is competent in developing, implementing, and maintaining the national DNA database. It further shows that the government can apply Fourth Amendment to develop a national wide DNA database to improve public safety. Every citizen should submit their DNA sample to relevant authorities, as they provide their fingerprints. It should be mandatory since it concerns public safety.

12.0 Recommendation

There are many things to be done so that the United States and other countries can realize the full potential of DNA databases in solving crimes. The first step would be the elimination of backlogs. This can be solved through a timely analysis where the biological samples from the crime scene are analyzed immediately after collection. For instance, in 1995, the Florida Department of Law Enforcement, through DNA analysis, linked a crime suspect to a rape case after being scheduled for parole in eight days (Department of Justice, 2020). Therefore, the suspect would have been released and probably committed the same crime without the DNA analysis. This shows that eliminating the backlog in DNA analysis can solve tragic results from law enforcement decisions.

The government should also concentrate on strengthening the crime laboratory capacity. Currently, most national laboratories cannot analyze the massive DNA caseloads. This has resulted in backlogs that delay the delivery of justice. For instance, a 2001 survey by the Bureau of Justice Statistics found that up to 2000, there was a 73% increase in DNA casework, which resulted in a 135% increase in the case backlog (Department of Justice, 2020). This shows that the cases should have been analyzed on time as required. As a result, the criminal justice system cannot fully benefit from the DNA database. The laboratory infrastructure improvement will be beneficial in reducing backlogs and helping the criminal justice system achieve the full potential of justice delivery.

The government should also stimulate research and development before implementing the DNA database. For the criminal justice system to fully benefit from DNA analysis, it should develop massive technology to hold the data collected and simultaneously protect it from breaching. The system should be low-cost and, at the same time, provide the required results (Department of Justice, 2020). This could be achieved through massive research and funding. The government should understand that the DNA database will hold sensitive information that should not be rigged for third parties. The information should be only used for healthcare research and criminal investigation purpose. It should not be used for business purposes as big data. The technology should be complicated and available to all DNA laboratories in the United States (Department of Justice, 2020). The laboratory officer should also be trained and capable of giving correct results. Forensic scientists should engage criminal detectives to help them advance the applicability of DNA processing at crime scenes. This will help improve the accuracy of DNA collection and processing, leading to fairness in justice delivery.

The government should engage in massive training for law enforcement officers. The officers should be trained to look for DNA samples, store the DNA evidence, and correctly process it in the laboratory. They should also be trained to eliminate the suspects using the DNA samples and differentiate implanted DNA samples from genuine ones. They should also be medically trained to ensure their forensic skills are effective in collecting and analyzing the collected samples (Department of Justice, 2020). Other officers such as defense attorneys, judges, and prosecutors should also be trained to apply the DNA evidence to ensure the plaintiff or defendant gets the deserved justice.

Therefore, after implementing the above recommendations, the government should go to the final phase, implementing a universal DNA database. Like Colona testing, the government should make it mandatory for everyone arrested for certain crime, as well as anyone who volunteers to do so, to provide DNA samples to the law enforcement database. The exercise should be conducted nationwide, and the FBI should be responsible for DNA collection and processing (Department of Justice, 2020). They should set up stations in each state with the help of state government and local authorities. The law should be enacted to ensure everyone who provides DNA samples have their information protected from third parties.

13.0 Conclusion

DNA phenotyping is an essential process in the criminal justice department. It is used to identify victims of disasters, offenders, and murderers using visible body parts such as hair, blood, and bones. The DNA strands are analyzed from these parts and compared to those reserved in the profiling database. The main issue with DNA phenotyping is the need for matching due to the limitation of DNA submission. Most countries do not recognize DNA evidence in court; it is only used for identification. Therefore, the laws need to be amended and make DNA profiling primary evidence in courts, like finger prints, for individuals arrested for certain crimes. This can help in solving unsolved and pending cases with DNA remains. The government should formulate laws that encourage citizens to submit their DNA samples to be filed with relevant agencies for purpose of building exemplary national DNA database (3G database).

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