

"Bridging Science and Society: The Interrelation of DNA Profiling, Criminal Investigation and Public Health" – A review

Shivangi Vyas¹

¹PhD scholar, Gujarat national law university, Gandhinagar Gujrat.

KEYWORDS

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ABSTRACT:

DNA profiling has emerged as one of the most transformative tools in modern science, significantly impacting criminal justice and public health. Its ability to identify individuals with unparalleled precision has revolutionized investigative procedures, facilitated justice, and informed health strategies. Despite its profound benefits, DNA profiling intersects with complex ethical, legal, and philosophical questions, particularly in the realms of privacy, human rights, and the potential misuse of genetic information. The evolution of DNA profiling technology, from its early applications in forensic science to its expanded roles in disease prevention and personalized medicine, highlights its multifaceted utility. In criminal investigations, DNA profiling aids in identifying perpetrators, exonerating the innocent, and solving cold cases. However, its integration raises concerns about privacy, potential stigmatization, and the erosion of the presumption of innocence. In public health, DNA profiling offers insights into genetic predispositions and fosters advancements in precision medicine, yet it also poses challenges regarding ethical use and equity. From a theoretical perspective, DNA profiling engages with criminological frameworks such as Cesare Lombroso's "born criminal" theory and modern understandings of sociological and environmental determinants of crime. This interplay underscores the nuanced relationship between biology and behaviour, challenging deterministic views of criminality. This article examines the interrelation between criminal investigations, public health, and DNA profiling, emphasizing the need for a balanced approach that maximizes benefits while mitigating risks. It concludes by advocating for policies and practices that uphold ethical standards, protect individual rights, and ensure the equitable application of DNA technologies.

Introduction

The intersection of science and societal needs has historically transformed methodologies in law enforcement and public health. DNA profiling, a cornerstone of modern forensic science, epitomizes this transformation.¹ Developed from foundational studies by James Watson and Francis Crick, and later operationalized by Alec Jeffreys, DNA profiling has evolved from a niche forensic tool to a widely utilized technology impacting diverse fields. Its application spans criminal investigations, paternity disputes, disaster victim identification, and public health initiatives.²

DNA profiling's efficacy lies in its ability to analyse unique genetic markers, enabling the identification of individuals with extraordinary precision. Forensic applications leverage biological samples such as blood, saliva, and hair to create DNA profiles, linking individuals to crime scenes or excluding them from suspicion. This technology has redefined justice delivery, bolstering the principles of fair trial and exoneration of the innocent, as seen in landmark cases like the Colin Pitchfork investigation in the United Kingdom and the work of The Innocence Project in the United States.^{3,4} Parallely, DNA profiling's implications for public health are profound. Genetic insights enable early disease detection, personalized treatment, and population screening, aligning with precision medicine's goals. However, these advancements raise significant ethical questions about privacy, equity, and the potential misuse of genetic data. Policies governing DNA databanks—repositories of genetic information—often navigate the delicate balance between utility and individual rights.^{5,6}

Theories of crime further complicate the discourse. Early deterministic models, such as Cesare Lombroso's "born criminal" hypothesis, attributed criminal behaviour to biological predispositions. Modern criminology integrates genetic, psychological, and environmental factors, presenting a more nuanced understanding. DNA profiling, while offering unprecedented insights, risks reinforcing outdated notions of biological determinism if misapplied.⁷

This article aims to unpack the multifaceted dimensions of DNA profiling, exploring its integration into criminal investigations and public health while critically analysing its alignment with criminological theories. Through this examination, it seeks to illuminate the potential of DNA

profiling to advance societal goals while cautioning against ethical pitfalls and advocating for responsible implementation.^{8,9}

Concept of DNA Profiling¹⁰

DNA profiling, also known as genetic fingerprinting, is a scientific technique used to identify individuals based on their unique genetic code. The foundation of DNA profiling lies in the discovery of deoxyribonucleic acid (DNA) by James Watson and Francis Crick in 1953, followed by Alec Jeffreys' development of DNA fingerprinting in the 1980s. This process examines specific regions of DNA known as short tandem repeats (STRs), which vary greatly among individuals, making them ideal for identification purposes. The process of DNA profiling typically involves the collection, extraction, amplification, and analysis of DNA. Biological samples such as blood, hair, saliva, or skin cells are collected from a crime scene or an individual. The DNA is then extracted and amplified using polymerase chain reaction (PCR) technology, which creates multiple copies of the DNA for analysis. Once amplified, the DNA is analysed to identify STR patterns, which are compared against a reference sample or a database.^{11,12}

Applications of DNA profiling extend beyond criminal investigations. In civil cases, DNA profiling resolves paternity disputes and immigration claims. In mass disasters, it aids in identifying victims. Additionally, advancements in genetic analysis have expanded its role to include ancestry tracing and personalized medicine. Despite its precision, DNA profiling is not without limitations. Issues such as contamination, partial profiles, and statistical misinterpretation can affect reliability. Ethical concerns also arise regarding the collection and storage of DNA, particularly without consent. DNA databases, while invaluable for solving crimes, pose risks of misuse and potential infringement on privacy rights. Balancing the benefits of DNA profiling with its ethical and legal challenges remains a critical concern for policymakers and practitioners.¹³

DNA Profiling and Criminal Investigation

DNA profiling has become an indispensable tool in modern criminal investigations, significantly enhancing the ability of law enforcement agencies to solve crimes, identify perpetrators, and exonerate the innocent. The integration of DNA profiling into criminal investigations has revolutionized law enforcement and judicial processes. Its unparalleled accuracy in identifying individuals has made it a cornerstone of modern forensic science, providing critical evidence in cases ranging from violent crimes to property offenses.^{14,15}

DNA profiling aids in solving crimes by linking suspects to evidence found at crime scenes. Biological samples such as blood, semen, or hair can establish a suspect's presence or absence. This capability has been pivotal in cases such as the Colin Pitchfork murder investigation, where DNA evidence led to the first criminal conviction using genetic profiling. Similarly, cold cases have been solved by re-analysing old evidence with advanced DNA technologies. Exoneration of wrongfully convicted individuals is another significant contribution of DNA profiling. Organizations like The Innocence Project have leveraged DNA evidence to overturn convictions, freeing individuals who spent decades in prison for crimes they did not commit. These cases underscore the technology's role in safeguarding justice.¹⁶

Key applications of DNA profiling in criminal investigations include:¹⁷

- **Matching Suspects to Crime Scenes:** DNA evidence recovered from crime scenes can be compared with DNA profiles from suspects. A match establishes a strong link between the suspect and the crime.
- **Identifying Unknown Perpetrators:** DNA profiles from crime scenes can be searched against DNA databases, potentially identifying perpetrators even if they are not initially suspects.
- **Linking Multiple Crimes:** DNA evidence can connect seemingly unrelated crimes, revealing serial offenders or establishing patterns of criminal activity.
- **Exonerating the Wrongfully Convicted:** DNA testing has played a crucial role in overturning wrongful convictions, demonstrating the fallibility of eyewitness accounts and other traditional forms of evidence.
- **Cold Case Investigations:** DNA evidence can provide new leads in cold cases, helping to solve crimes that have remained unsolved for extended periods.

However, the use of DNA profiling in criminal investigations raises critical ethical and legal questions. The collection of DNA samples from arrestees, regardless of conviction status, challenges the principle of presumption of innocence. Storing DNA profiles in databases, such as the FBI's CODIS, facilitates crime solving but also poses risks of misuse and discrimination. From a procedural perspective, maintaining the integrity of DNA evidence is paramount. Issues such as contamination, chain-of-custody lapses, and interpretative biases can undermine the credibility of DNA evidence in court. Additionally, public perception of DNA as infallible—popularized by media portrayals—can lead to the "CSI effect," where jurors overestimate its reliability.

Addressing these challenges requires robust legal frameworks, stringent quality controls in forensic laboratories, and public education about the strengths and limitations of DNA evidence. When employed responsibly, DNA profiling enhances the pursuit of justice, making it an indispensable tool in criminal investigations.¹⁸

DNA Profiling and Public Health¹⁹

Beyond its forensic applications, DNA profiling has significant implications for public health. By analysing genetic information, researchers and healthcare providers can gain insights into disease predispositions, inform preventive measures, and advance personalized medicine.

One of the primary public health applications of DNA profiling is genetic testing for disease susceptibility. By identifying genetic markers associated with conditions such as cancer, cardiovascular diseases, or neurological disorders, individuals can take proactive measures to mitigate risks. For instance, the identification of BRCA1 and BRCA2 gene mutations enables early intervention strategies for breast and ovarian cancer. Pharmacogenomics, the study of how genes affect drug responses, represents another transformative application. DNA profiling helps tailor medical treatments to an individual's genetic makeup, improving efficacy and minimizing adverse effects. This personalized approach to medicine has the potential to revolutionize healthcare delivery.

In population health, DNA profiling supports epidemiological studies by identifying genetic factors contributing to disease prevalence in specific groups. This knowledge informs targeted public health interventions and resource allocation. Additionally, DNA-based newborn screening programs have been instrumental in detecting genetic disorders early, improving outcomes through timely treatment.

However, the integration of DNA profiling into public health is fraught with challenges. Ethical concerns about genetic privacy, informed consent, and potential discrimination must be addressed. The equitable distribution of benefits from genetic advancements is another critical issue, as access to DNA-based healthcare may be limited by socioeconomic factors.

To maximize the benefits of DNA profiling in public health, it is essential to establish regulatory frameworks that protect individual rights while promoting scientific innovation. Public engagement and education are also crucial in fostering trust and understanding of genetic technologies.

DNA Profiling and Theories of Crime²⁰

The relationship between DNA profiling and criminological theories provides a fascinating lens to examine the biological, psychological, and social dimensions of crime. Historical theories, such as Cesare Lombroso's "born criminal" hypothesis, posited that criminality was biologically predetermined. While these deterministic views have been largely discredited, the advent of DNA profiling rekindles debates about the biological underpinnings of criminal behaviour. Modern criminology integrates biological factors with environmental and sociological influences. Research into genetic predispositions suggests that certain genetic variations may increase susceptibility to impulsive or aggressive behaviour. However, these tendencies are mediated by environmental factors such as upbringing, social context, and individual experiences. The ethical implications of linking genetics to criminality are profound. Misinterpreting genetic data risks stigmatizing individuals or groups, reinforcing stereotypes, and perpetuating discrimination. Such misapplications echo Lombroso's flawed theories, emphasizing the need for caution and nuanced interpretation of genetic findings.²¹

DNA profiling also intersects with psychological and sociological theories of crime. Behavioural genetics explores how genetic predispositions interact with environmental triggers to influence criminal behaviour. Understanding these dynamics can inform rehabilitative strategies and crime prevention policies, moving beyond punitive approaches to address root causes. By integrating insights

from multiple disciplines, DNA profiling enriches the understanding of crime while highlighting the complexities of human behaviour. Responsible application of this knowledge can contribute to a more just and effective criminal justice system.²²

DNA Profiling, Criminal Investigation and Public Health – Interrelation

DNA profiling's impact on criminal investigations and public health illustrates its transformative potential across domains. These applications are interconnected, reflecting broader implications for society. In criminal investigations, DNA profiling enhances justice delivery by identifying perpetrators, exonerating the innocent, and deterring crime through the existence of genetic databases. In public health, it advances personalized medicine, informs disease prevention, and supports population health initiatives. Both domains share a reliance on the accuracy, integrity, and ethical use of genetic information.²³

The interrelation is evident in cases where public health data supports criminal investigations. For example, DNA collected during public health screenings has occasionally been used in criminal probes, raising questions about consent and the scope of data use. Balancing public safety with individual rights requires clear policies delineating permissible uses of genetic information. Additionally, the ethical considerations surrounding DNA profiling are shared across domains. Privacy concerns, the risk of misuse, and the need for equitable access to benefits are central to both criminal justice and public health. Collaborative efforts among scientists, ethicists, policymakers, and the public are essential in addressing these challenges.

By fostering dialogue and implementing safeguards, society can harness the potential of DNA profiling while upholding ethical standards and protecting individual rights. The interplay between criminal investigations and public health underscores the need for a holistic approach to genetic technologies, ensuring they serve as tools for progress and justice.²⁴⁻¹⁶

Conclusion

DNA profiling stands at the intersection of science, law, and ethics, offering unprecedented opportunities to advance criminal justice and public health. Its ability to identify individuals with precision has transformed investigative procedures, facilitated justice, and informed healthcare strategies. However, the integration of DNA profiling into these domains requires careful consideration of ethical, legal, and societal implications.

The evolution of DNA profiling reflects its versatility and potential. In criminal investigations, it has enhanced the accuracy of convictions, supported the exoneration of the innocent, and provided a powerful deterrent against crime. In public health, it has informed disease prevention, enabled personalized medicine, and contributed to population health research. These advancements underscore the technology's utility and relevance in addressing societal challenges. Yet, the ethical complexities of DNA profiling demand vigilance. Issues of privacy, consent, equity, and potential misuse necessitate robust regulatory frameworks and ongoing public engagement. The risk of reinforcing outdated notions of biological determinism highlights the importance of integrating scientific advancements with nuanced understanding and ethical principles. The intersection of criminal investigations, public health, and DNA profiling illustrates the interconnectedness of societal domains. By fostering interdisciplinary collaboration and promoting ethical practices, society can maximize the benefits of DNA profiling while safeguarding individual rights and societal values.

In the era of navigating the promises and perils of genetic technologies, a balanced approach that prioritizes justice, equity, and innovation is essential. DNA profiling, when employed responsibly, has the potential to not only solve crimes and save lives but also to advance our understanding of humanity and our collective potential for progress.

References

1. Doshi, K. (2022). DNA Profiling: A Magic Bullet or a Wonderland of Uncertainty.
2. Parven, K. (Year). Forensic Use of DNA Information v Human Rights and Privacy Challenges.
3. Ahmed, S. (2022). DNA Profiling and Human Right: Issue and Challenges for Application in Administration of Criminal Justice.
4. Balding, D. J. (2000). Interpreting DNA Evidence: Can Probability Theory Help?
5. Creation of DNA Databanks and the Theory of Born Criminals: A Critical Examination.

6. History, Ideology, and Evolution of Criminal Profiling. 10-25. Additional references will include foundational studies, legal frameworks, and contemporary research articles on DNA profiling, criminal justice, and public health.
7. Amankwaa, A. O., & McCartney, C. (2021). The effectiveness of the current use of forensic DNA in criminal investigations in England and Wales. *WIREs Forensic Science*, 3(6). <https://doi.org/10.1002/wfs2.1414>
8. Bennett, E. A., & Anderson, R. S. (1991). DNA Profiling. *Advocate (Vancouver)*, 49, 63.
9. Bernstein, D. E., & Jackson, J. D. (2004). The Daubert Trilogy in The States. *American Bar Association*, 44, 3351–66.
10. Blair, C. T. (1990). Spencer v Commonwealth and Recent Developments in the Admissibility of DNA Fingerprint Evidence. *Virginia Law Journal*, 76, 853.
11. Butler, J. M. (2015). The Future of Forensic DNA analysis. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1674), 1–10. <https://doi.org/10.1098/rstb.2014.0252>
12. Campbell, L. (2010). A Rights-Based Analysis of DNA Retention: "Non-Conviction" Databases and the Liberal State. *Criminal Law Review*, 12, 889.
13. Chambers, G. K., Cordiner, S. J., Buckleton, J. S., Robertson, B., & V, G. A. (1997). Forensic DNA Profiling: The Importance of Giving Accurate Answers to the Right Questions. [Journal Name Missing], 8(3), 445–459.
14. Clarke, G., & Reno, J. (2007). *Justice and Science: Trials and Triumphs of DNA Evidence*. Rutgers University Press.
15. Committee on DNA Technology in Forensic Science. (1992). *DNA Technology in Forensic Science*. National Academy Press.
16. Daves, A. (1991). The Use of DNA Profiling and Behavioural Science in the Investigation of Sexual Offences. *Medicine, Science and the Law*, 31(2), 95–101. <https://doi.org/10.1177/002580249103100202>
17. DNA Technology in Forensic Science. (1992). <https://doi.org/10.17226/1866>
18. Friedman, A. L. (1999). Forensic DNA profiling in the 21st century. *International Journal of Offender Therapy and Comparative Criminology*, 43(2), 168–179. <https://doi.org/10.1177/0306624X99432004>
19. Gabel, J. D. (2019). Realizing Reliability in Forensic Science from the Ground up. *The Journal of Criminal Law and Criminology*, 104(2), 283–352. Stable URL: <https://www.jstor.org/stable/44113391>
20. Gardiner, G. (2005). 'Racial Profiling': DNA Forensic Procedures and Indigenous People in Victoria. *Current Issues in Criminal Justice*, 17(1), 47–68. <https://doi.org/10.1080/10345329.2005.12036335>
21. Gill, P. (2001). Application of low copy number DNA profiling. *Croatian Medical Journal*, 42(3), 229–232.
22. Gill, P. (2005). DNA as Evidence — The Technology of Identification. *The New England Journal of Medicine*, 352(26), 2669.
23. Gill, P., & Buckleton, J. (2005). Biological Basis for DNA Evidence. In J. S. Buckleton, C. M. Triggs, & S. J. Walsh (Eds.), *Forensic DNA Evidence Interpretation* (pp. 1–2). CRC Press.
24. Heinemann, T., Lemke, T., & Prainsack, B. (2012). Risky profiles: Societal dimensions of forensic uses of DNA profiling technologies. *New Genetics and Society*, 31(3), 249–258. <https://doi.org/10.1080/14636778.2012.687132>
25. Hoeffel, J. C. (1990). The Dark Side of DNA Profiling: Unreliable Scientific Evidence Meets the Criminal Defendant. *Stanford Law Review*, 42(2), 465. <https://doi.org/10.2307/1228965>
26. Jordan, D., & Mills, D. E. (2021). Past, Present, and Future of DNA Typing for Analyzing Human and Non-Human Forensic Samples. *Frontiers in Ecology and Evolution*, 9. <https://doi.org/10.3389/fevo.2n021.646130>