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DNA DATABANKS IN FORENSIC SCIENCE: APPLICATIONS, CHALLENGES AND FUTURE PERSPECTIVES

BY

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Abstract
DNA databanks have become an essential component of modern forensic science, significantly enhancing human identification in criminal investigations, disaster victim identification, and missing persons cases. This study provides a critical appraisal of the applications, challenges, and future perspectives of DNA databanks within forensic practice. A narrative review approach was employed, drawing on evidence from major scientific databases, including PubMed, and Google Scholar. Findings indicate that DNA databanks improve the efficiency and accuracy of forensic investigations through rapid comparison of genetic profiles, linkage of suspects to crime scenes, and resolution of previously unsolved cases. However, their implementation is constrained by ethical concerns, legal complexities, data privacy issues, and disparities in infrastructure, particularly in developing countries. In addition, challenges related to database management, population representation, and misuse of genetic information remain significant. Future perspectives emphasize the need for robust regulatory frameworks, improved data protection policies, expansion of population-specific databases, and integration of advanced genomic technologies. Strengthening governance and ensuring ethical compliance are critical to maximizing the potential of DNA databanks while maintaining public trust.
Keywords: DNA databank, Forensic science, DNA profiling, Human identification, Forensic genetics

Introduction

Forensic genetics has transformed the landscape of human identification, establishing DNA analysis as one of the most powerful tools in modern criminal investigations. The advent of short tandem repeat (STR) profiling marked a pivotal shift from conventional identification methods to highly precise, reproducible genetic techniques capable of generating reliable profiles from minimal or degraded biological samples (Haddrill, 2021). As a result, DNA evidence now plays a central role in linking individuals to crime scenes, resolving complex cases, and supporting judicial decision-making. The expansion of DNA databanks has further amplified the utility of forensic genetics by enabling large-scale storage, comparison, and retrieval of genetic profiles. Early systems such as the United Kingdom's National DNA Database (NDNAD) and the United States' Combined DNA Index System (CODIS) established the foundation for modern forensic databanking by facilitating automated matching between crime scene samples and known individuals (Amankwaa & McCartney, 2021; Uberoi et al., 2024). These systems introduced the concept of database-driven investigation, where "cold hits" can identify suspects in the absence of prior leads, fundamentally reshaping investigative strategies.

In contemporary criminal justice systems, DNA databanks have become indispensable tools, playing a crucial role in solving violent crimes, sexual offences, and complex serial investigations. They also contribute significantly to identifying missing persons and facilitating post-conviction exonerations, thereby enhancing both investigative accuracy and judicial fairness. As forensic technologies continue to advance, the scope and utility of DNA databases have expanded, making them central to modern law enforcement practices. However, the rapid growth of these databanks has brought with it a range of ethical, legal, and technical concerns. Issues related to genetic privacy and informed consent have become increasingly prominent, particularly as individuals' sensitive biological information is stored and potentially accessed for extended periods. Questions surrounding data retention policies and the possible misuse of genetic information further complicate the landscape. These concerns are amplified by the emergence of investigative genetic genealogy, a technique that extends DNA analysis beyond traditional databases to include familial and ancestry-based searches (Uberoi et al., 2024). Moreover, technical and structural challenges persist. Unequal representation within DNA databases can lead to biases, raising concerns about fairness and equity in criminal investigations. The risk of false matches, especially in large and expanding datasets, also poses questions about reliability. In addition, cybersecurity threats highlight the vulnerability of sensitive genetic information to unauthorized access or breaches (Alketbi, 2024; Butler, 2022; Uberoi et al., 2024). These issues underscore the tension between the increasing capabilities of DNA databanks and the necessity for robust oversight. This review critically examines their applications, associated challenges, and future directions, with the goal of informing policy development, improving forensic practices, and ensuring that advancements in forensic genetics are guided by ethical principles and public confidence.

Research Objectives

1. To evaluate the applications of DNA databanks in forensic science, particularly in criminal investigations, case linkage, and human identification.
2. To examine the ethical, legal, and technical challenges associated with DNA databanking, with emphasis on privacy, consent, data governance, and reliability.
3. To assess emerging technologies influencing DNA databanks, including genomic advancements and data-driven analytical systems, and their implications for future forensic practice.

Research Questions

1. How are DNA databanks applied in forensic investigations and criminal justice systems?
2. What ethical, legal, and technical challenges are associated with the use of DNA databanks?
3. How are emerging technologies shaping the future of DNA databanks in forensic science?

Methodology

This study adopted a narrative literature review approach to provide a comprehensive and concept-driven synthesis of existing knowledge on DNA databanks in forensic science. A structured literature search was conducted using PubMed and Google Scholar, selected for their broad coverage of biomedical, forensic, and interdisciplinary research. The search, last updated in March 2026, employed keywords and Boolean combinations such as "DNA databank," "forensic DNA database," "CODIS," and "NDNAD," alongside terms related to applications, ethics, privacy, and emerging technologies including next-generation sequencing and investigative genetic genealogy. Inclusion criteria comprised peer-reviewed articles, review papers, and policy-relevant publications published between 2015 and 2026, with additional foundational studies included where necessary. Exclusion criteria included purely clinical or medical genetics studies unrelated to forensic applications, non-English publications, and sources lacking sufficient methodological or analytical depth. Selected studies were analyzed qualitatively using a thematic synthesis approach, with findings organized around key domains aligned with the study objectives, including applications, challenges, and future perspectives. Comparative insights across jurisdictions and databanking systems were incorporated to highlight variations in practice and governance. Although this narrative approach does not involve formal risk-of-bias assessment and may be subject to selection bias, it provides a structured and comprehensive framework for evaluating DNA databanks within contemporary forensic science.

Results

Applications of DNA Databanks in Forensic Science

DNA databanks play a central role in modern criminal investigations by enabling the rapid comparison of genetic profiles across large and continuously expanding datasets (Butler, 2022; Amankwaa & McCartney, 2021; Wickenheiser, 2022). Through standardized short tandem repeat (STR) profiling systems, forensic samples recovered from crime scenes can be compared against stored profiles of known offenders, arrestees, or previously collected forensic samples (Haddrill, 2021; Butler, 2022). This facilitates both direct matches, where a suspect is identified through database comparison, and "cold hits," where unknown profiles are linked to individuals without prior investigative leads (Amankwaa & McCartney, 2021; Wickenheiser, 2022). Such capabilities have significantly enhanced case resolution rates, particularly in serious offences where biological evidence is present, and have reduced reliance on traditional suspect-driven investigative approaches (Butler, 2022; Uberoi *et al.,* 2024). Beyond individual case resolution, DNA databanks are instrumental in linking multiple crime scenes to a single perpetrator through forensic-to-forensic matching (Kayser, 2015; Wickenheiser, 2022). This allows investigators to identify serial offenders by detecting recurring DNA profiles across different locations and time points (Butler, 2022). Furthermore, DNA databanks contribute to intelligence-led policing by facilitating large-scale data integration and pattern recognition (Amankwaa, 2019; Uberoi *et al.,* 2024). The ability to cross-reference forensic evidence across jurisdictions enhances collaboration between law enforcement agencies and supports the detection of transnational crime networks (Uberoi *et al.,* 2024).

Humaitarian Identification and Missing Person Reolution

DNA databanks also serve critical functions in humanitarian contexts, particularly in the identification of missing persons and previously unidentified human remains (Kayser, 2015; Butler, 2022). Through kinship-based matching, DNA profiles from unidentified remains can be compared with those of biological relatives, enabling the reconstruction of familial relationships and facilitating accurate identification (Slooten, 2018; Ferreira *et al.*, 2025).These applications are especially relevant in cases involving mass disasters, conflicts, and long-term disappearances, where conventional identification methods such as visual recognition or fingerprint analysis are not feasible (Kayser, 2015; Wickenheiser, 2022). DNA databanks therefore provide a reliable and scientifically robust approach to resolving complex identification challenges and supporting medico-legal processes**.**

Post-Conviction Analysis and Judicial Review

Beyond investigative and humanitarian roles, DNA databanks contribute to post-conviction processes by enabling the re-analysis of biological evidence using improved technologies and expanded databases (Butler, 2022; Wickenheiser, 2022). This allows for the identification of true perpetrators in cases where initial investigations were inconclusive or based on limited evidence (Amankwaa & McCartney, 2021). Importantly, DNA databanks support the exoneration of wrongfully convicted individuals by providing objective genetic evidence capable of overturning prior convictions. This underscores their role not only as investigative tools but also as mechanisms for ensuring fairness and accuracy within the criminal justice system (Wickenheiser, 2022; Butler, 2022).

Challenges in DNA Databanking: Ethical, Legal, and Technical Dimensions

First, the expansion of DNA databanks raises significant ethical concerns, particularly regarding genetic privacy and informed consent (Amankwaa, 2019; Dahlquist, 2025; Guerrini *et al.,* 2025). While DNA profiles are primarily used for identification, they may also reveal sensitive information about familial relationships and genetic traits, creating potential risks for misuse (Uberoi *et al.,* 2024). The inclusion of individuals in databanks without explicit consent further intensifies these concerns. Techniques such as familial searching and investigative genetic genealogy extend the scope of databank use beyond individuals to their biological relatives, raising additional ethical questions about autonomy and the boundaries of forensic surveillance (Duan *et al.*, 2025; Gurney, 2025). These issues highlight the need for clear ethical guidelines governing the use of genetic data. Second, legal frameworks governing DNA databanks vary considerably across jurisdictions, particularly with respect to policies on data retention, access, and deletion (Amankwaa, 2019; Zaretsky, 2021). In the United Kingdom, earlier policies permitted the retention of DNA profiles from individuals who were arrested but not convicted, a practice later challenged under human rights law and revised through the Protection of Freedoms Act 2012, which introduced stricter retention limits (Uberoi *et al.*, 2024). In contrast, the United States operates a decentralized system under the Combined DNA Index System (CODIS), where retention and expungement policies are largely determined at the state level, resulting in variability in the inclusion of arrestees and convicted offenders. These differences reflect distinct legal approaches to balancing crime control with the protection of individual rights. Such variability creates challenges in ensuring consistency and fairness in the application of DNA databanking practices. Differences in retention thresholds and access policies influence how individuals are represented within databases and shape the balance between investigative utility and civil liberties (Amankwaa, 2019). These disparities become particularly significant in cross-jurisdictional investigations, where differing legal standards complicate data exchange and the mutual recognition of forensic evidence. The absence of harmonized regulatory frameworks further limits the development of standardized forensic practices and coordinated international use of DNA databanks. As databanking systems continue to expand globally, these legal inconsistencies remain a key operational consideration in the effective and equitable use of forensic genetic data. Third, despite their effectiveness, DNA databanks are subject to several technical limitations that can affect reliability and interpretation (Butler, 2022; Alketbi, 2024). One major issue is database bias, where certain populations are overrepresented while others are underrepresented, potentially influencing the accuracy and equity of forensic outcomes. Additionally, the risk of false matches increases as database size expands, necessitating careful validation and interpretation of results. Challenges associated with degraded or low-template DNA samples further complicate analysis, particularly in resource-limited countries (Haddrill, 2021). These limitations underscore the need for continuous improvement in forensic technologies and databank management systems.

Future Perspectives of DNA Databanks in Forensic Science

Emerging genomic technologies are significantly expanding the capabilities of DNA databanks by enabling more comprehensive genetic analysis beyond traditional short tandem repeat (STR) profiling (Ferreira et al., 2025). Next-generation sequencing (NGS) allows for the simultaneous analysis of multiple genetic markers, including single nucleotide polymorphisms (SNPs), thereby increasing the resolution and discriminatory power of forensic identification. This is particularly valuable in cases involving degraded or low-template DNA, where conventional STR-based methods may be limited (Haddrill, 2021). In addition to improving identification accuracy, NGS facilitates more detailed genetic characterization, enabling the analysis of complex kinship relationships that extend beyond immediate familial links (Haddrill, 2021). This enhances the ability of DNA databanks to support identification in challenging scenarios such as missing persons cases or mass fatality incidents, where indirect genetic relationships may need to be established (Ferreira et al., 2025). The expanded analytical scope provided by genomic technologies therefore strengthens the overall utility of databanking systems in forensic applications. Furthermore, advancements in genomic sequencing technologies have improved the efficiency and scalability of forensic DNA analysis. High-throughput sequencing platforms allow for the processing of large volumes of samples with increased speed and precision, supporting the growing demands placed on DNA databanks (Ferreira et al., 2025; Haddrill, 2021). As these technologies continue to evolve, they contribute to the development of more robust and comprehensive genetic databases capable of supporting a wide range of forensic identification needs. The integration of artificial intelligence (AI) and machine learning into forensic DNA systems presents new opportunities for enhancing data analysis and interpretation. These technologies can support automated pattern recognition, improve database searching algorithms, and assist in the interpretation of complex DNA mixtures, which are often challenging using conventional methods (Sessa, 2024; Walker, 2025). By increasing analytical precision and reducing manual workload, AI-driven systems have the potential to improve both the speed and accuracy of forensic identification processes ((Barash, 2024). However, the application of AI in forensic contexts introduces important considerations related to validation, transparency, and bias. Algorithmic decision-making must be rigorously tested to ensure reliability and reproducibility, particularly in legal settings where forensic evidence must withstand judicial scrutiny (Sessa, 2024; Walker, 2025). In addition, concerns regarding algorithmic bias and data quality highlight the need for careful oversight and standardized implementation frameworks as these technologies become more integrated into forensic databanking systems. The continued evolution of DNA databanks necessitates the development of robust governance frameworks capable of accommodating technological advancements while ensuring ethical and legal compliance. This includes the establishment of clear policies governing data collection, retention, access, and sharing, as well as the implementation of standardized operational protocols across forensic systems. Effective governance is essential for maintaining consistency, accountability, and trust in the use of genetic data (Amankwaa, 2019; Uberoi et al., 2024). In addition, future DNA databanking systems must address issues of inclusivity and representation to improve the accuracy and equity of forensic analyses. Underrepresentation of certain populations within databases can affect match probabilities and limit the effectiveness of identification processes (Butler, 2022). As such, efforts to expand and diversify DNA databases, alongside strengthened data protection measures and transparent regulatory oversight, remain critical considerations in the ongoing development of forensic DNA databanking systems.

Discussion

The findings of this review demonstrate that DNA databanks have become central to contemporary forensic science, with broad applications across criminal investigations, humanitarian identification, and post-conviction review. Their ability to enable rapid comparison of genetic profiles and generate investigative leads has improved the efficiency and scope of forensic inquiry, particularly in complex and serial cases (Butler, 2022; Amankwaa & McCartney, 2021). These applications are inherently interconnected, as the same databank infrastructure that supports criminal case resolution also underpins missing persons identification and judicial review processes

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(Zaretsky, 2021). This reflects the multifunctional role of DNA databanks as integrated systems within modern justice frameworks rather than isolated investigative tools. However, the expansion of DNA databanks introduces a range of ethical, legal, and technical challenges that directly influence their reliability and societal acceptance. The storage and use of genetic data raise concerns regarding privacy, consent, and the potential misuse of sensitive information, particularly as techniques such as familial searching extend identification beyond individuals to their biological relatives (Amankwaa, 2019; Uberoi et al., 2024). In addition, variations in legal frameworks governing data retention and access create inconsistencies in implementation, while database bias and the risk of false matches in large datasets present challenges to the accuracy and equity of forensic outcomes (Butler, 2022; Alketbi, 2024). These issues highlight the need to critically balance forensic utility with ethical responsibility.

The rapid advancement of forensic technologies further shapes the evolving role of DNA databanks by enhancing both analytical capacity and operational efficiency. Innovations such as next-generation sequencing and artificial intelligence enable more detailed genetic analysis and improved data interpretation, particularly in complex or degraded samples (Sessa, 2024; Walker, 2025). However, these advancements also introduce new considerations related to validation, standardization, and governance, as the increasing complexity of genetic data requires robust oversight mechanisms to ensure reliability and prevent misuse (Uberoi et al., 2024). This underscores the importance of aligning technological progress with regulatory and ethical safeguards. Within the Nigerian context, these findings emphasize the need for context-specific approaches to the development and implementation of DNA databanking systems. Establishing a national DNA database supported by clear legal frameworks for data collection, retention, and access is essential for effective application (Amankwaa, 2019). Strengthening forensic infrastructure, including laboratory capacity and professional training, will improve the reliability of DNA-based identification, particularly in resource-limited countries. Furthermore, the development of population-representative databases is critical for ensuring accuracy and reducing bias in forensic analysis (Butler, 2022). Integrating these measures with ethical guidelines and public engagement strategies will be necessary to build trust and support the responsible use of DNA databanks in Nigeria.

Conclusion

DNA databanks have become essential tools in forensic science, enhancing human identification across criminal investigations, humanitarian contexts, and post-conviction review. Their ability to enable rapid and large-scale comparison of genetic profiles has transformed forensic practice, improving both investigative efficiency and case resolution. However, their effectiveness is closely dependent on the presence of robust infrastructure, representative databases, and well-defined governance systems. As highlighted in this review, the expansion of DNA databanks is accompanied by significant ethical, legal, and technical challenges that must be addressed to ensure their reliability, equity, and public acceptance. To optimize their use, the development of clear legal frameworks governing data collection, retention, and access is essential, alongside sustained investment in forensic infrastructure and professional training. Establishing population-representative databases will improve the accuracy and applicability of forensic analyses, while the integration of emerging technologies must be supported by rigorous validation and ethical oversight. In the Nigerian context, a coordinated approach that combines policy development, capacity building, and public engagement is critical. By aligning technological advancement with governance and inclusivity, DNA databanks can be effectively leveraged to strengthen forensic practice and support the criminal justice system.

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