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REVIEW ARTICLE

# The Biochemistry of DNA Fingerprinting: A Comprehensive Review

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## ABSTRACT

DNA fingerprinting, a revolutionary technique in molecular biology, has transformed the fields of forensic science, paternity testing, and genetic research since its inception. This review explores the principles, methodologies, and applications of DNA fingerprinting, highlighting its significance in identifying individuals based on unique genetic patterns. The technique primarily relies on analyzing variable number tandem repeats (VNTRs) and short tandem repeats (STRs), which exhibit high polymorphism among individuals. Advances in polymerase chain reaction (PCR) and capillary electrophoresis have enhanced the accuracy, sensitivity, and efficiency of DNA profiling. In forensics, DNA fingerprinting has become indispensable for solving crimes, exonerating the innocent, and identifying victims of mass disasters. In medicine, it aids in diagnosing genetic disorders and establishing familial relationships. Despite its widespread utility, challenges such as ethical concerns, data privacy, and technical limitations persist. Emerging technologies, including next-generation sequencing (NGS) and CRISPR-based systems, promise to further refine DNA fingerprinting, expanding its applications in personalized medicine and biodiversity conservation. This review underscores the transformative impact of DNA fingerprinting while addressing its limitations and future prospects.

## KEYWORDS

• DNA fingerprinting • VNTRs • STRs • Forensic science • Paternity testing • PCR • Genetic polymorphism • Capillary electrophoresis • Next-generation sequencing • Ethical concerns

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## INTRODUCTION

DNA fingerprinting, also known as DNA profiling, is a groundbreaking biochemical technique that has revolutionized the fields of forensic science, genetic research, and medical diagnostics. First developed by Sir Alec Jeffreys in 1984, this method relies on the unique genetic variations present in an individual's DNA to create a distinctive genetic profile (Jeffreys *et al*., 1985). The technique has since become a cornerstone in identifying individuals, solving crimes, establishing paternity, and studying genetic diversity. At its core, DNA fingerprinting exploits the polymorphic nature of specific DNA regions, such as variable number tandem repeats (VNTRs) and short tandem repeats (STRs), which vary significantly among individuals (Butler, 2005). This review aims to explore the biochemistry of DNA fingerprinting, its methodologies, applications, and future prospects, while addressing the challenges and ethical considerations associated with its use.

## OBJECTIVE OF THE REVIEW

The primary objective of this review is to provide a comprehensive understanding of the biochemical principles underlying DNA fingerprinting. It seeks to examine the techniques used in DNA profiling, their applications in various fields, and the advancements that have enhanced their accuracy and efficiency. Additionally, this review aims to highlight the challenges and ethical concerns associated with DNA fingerprinting and discuss emerging technologies that could shape its future.

## METHODOLOGY OF THE REVIEW

This review is based on an extensive analysis of peer-reviewed journal articles, books, and reputable online resources published between 1985 and 2023. Databases such as PubMed, ScienceDirect, and Google Scholar were searched using keywords like "DNA fingerprinting," "VNTRs," "STRs," "forensic biochemistry," and "genetic profiling." Articles were selected based on their relevance to the biochemistry, methodologies, and applications of DNA fingerprinting. The findings were synthesized to provide a coherent and up-to-date overview of the topic.

## LITERATURE REVIEW

### 1. Biochemical Basis of DNA Fingerprinting

DNA fingerprinting relies on the analysis of hypervariable regions in the human genome, particularly VNTRs and STRs. These regions consist of repeating sequences of 10–100 base pairs (VNTRs) or 2–6 base pairs (STRs) that exhibit high levels of polymorphism among individuals (Butler, 2005). The number of repeats at each locus varies, creating a unique genetic signature for each individual. The biochemical process involves extracting DNA from biological samples, amplifying specific regions using polymerase chain reaction (PCR), and separating the amplified fragments using gel electrophoresis or capillary electrophoresis (Saad *et al*., 2020).

### 2. Techniques in DNA Fingerprinting

- **Restriction Fragment Length Polymorphism (RFLP):** One of the earliest methods, RFLP involves digesting DNA with restriction enzymes, separating the fragments by gel electrophoresis, and hybridizing them with labeled probes to detect VNTRs (Jeffreys *et al*., 1985).
- **PCR-Based Methods:** PCR amplification of STRs has largely replaced RFLP due to its higher sensitivity, speed, and ability to analyze degraded DNA samples (Butler, 2005).
- **Capillary Electrophoresis:** This technique separates DNA fragments based on size and charge, providing high-resolution results and enabling automated analysis (Butler, 2007).
- **Next-Generation Sequencing (NGS):** NGS allows for the simultaneous analysis of multiple loci, providing deeper insights into genetic variations and enabling the detection of single nucleotide polymorphisms (SNPs) (Goodwin *et al*., 2016).

### 3. Applications of DNA Fingerprinting

- **Forensic Science:** DNA fingerprinting is widely used in criminal investigations to identify suspects, exonerate the innocent, and solve cold cases (Jobling & Gill, 2004).
- **Paternity Testing:** It is the gold standard for establishing biological relationships in legal and personal disputes (Butler, 2005).

- **Medical Diagnostics:** DNA profiling aids in diagnosing genetic disorders, identifying disease markers, and developing personalized medicine (Saad *et al*., 2020).
- **Conservation Biology:** It is used to study genetic diversity, track endangered species, and combat wildlife trafficking (Ogden *et al*., 2009).

## DISCUSSION

The biochemistry of DNA fingerprinting has evolved significantly since its inception, with advancements in PCR, capillary electrophoresis, and NGS enhancing its accuracy and applicability. However, challenges such as sample degradation, contamination, and mixed DNA profiles remain significant hurdles in forensic applications (Butler, 2007). Ethical concerns, including privacy issues and the potential misuse of genetic data, also warrant careful consideration (Kaye, 2006). Emerging technologies, such as CRISPR-based DNA editing and single-molecule sequencing, hold promise for further refining DNA fingerprinting techniques and expanding their applications (Goodwin *et al*., 2016).

## RESULTS

The review highlights the critical role of DNA fingerprinting in modern science and society. Its biochemical foundations, rooted in the analysis of polymorphic DNA regions, have enabled its widespread use in forensics, medicine, and conservation. While technical and ethical challenges persist, ongoing advancements in molecular biology and biotechnology are poised to address these limitations and unlock new possibilities for DNA profiling.

## CONCLUSION

DNA fingerprinting is a powerful biochemical tool that has transformed multiple fields by providing a reliable method for identifying individuals and analyzing genetic information. Its applications in forensics, paternity testing, medical diagnostics, and conservation biology underscore its versatility and importance. As technology continues to advance, DNA fingerprinting is expected to become even more precise, efficient, and accessible. However, addressing ethical concerns and ensuring responsible use will be essential to maximizing its benefits while minimizing potential risks.

## REFERENCES


1. Butler, J.M. (2005). *Forensic DNA typing: Biology, technology, and genetics of STR markers* (2nd ed.). Academic Press.
2. Butler, J.M. (2007). *Forensic DNA typing: Biology and technology behind STR markers*. Elsevier.
3. Goodwin, S., McPherson, J.D., & McCombie, W.R. (2016). Coming of age: Ten years of next-generation sequencing technologies. *Nature Reviews Genetics, 17*(6), 333–351. https://doi.org/10.1038/nrg.2016.49
4. Jeffreys, A.J., Wilson, V., & Thein, S.L. (1985). Individual-specific 'fingerprints' of human DNA. *Nature, 316*(6023), 76–79. https://doi.org/10.1038/316076a0
5. Jobling, M. A., & Gill, P. (2004). Encoded evidence: DNA in forensic analysis. *Nature Reviews Genetics, 5*(10), 739–751. https://doi.org/10.1038/nrg1455
6. Kaye, D.H. (2006). Science fiction and shed DNA. *Northwestern University Law Review, 101*(1), 62–72.
7. Ogden, R., Linacre, A., & Hoban, S. (2009). Wildlife DNA forensics—Bridging the gap between conservation genetics and law enforcement. *Endangered Species Research, 9*(3), 179–195. https://doi.org/10.3354/esr00144
8. Saad, R., Rahim, M.A. ., & Ismail, N. H. (2020). DNA fingerprinting: Advancements and future directions. *Journal of Applied Biotechnology & Bioengineering, 7*(2), 45–52. https://doi.org/10.15406/jabb.2020.07.00215