



IN-DEPTH OVERVIEW OF DNA FINGERPRINTING: EXPLORING THE SCIENCE AND APPLICATIONS

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Abstract

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The advent of DNA fingerprinting has transformed criminal identification and forensic science. Much like traditional ink fingerprints, DNA fingerprints are distinct to each individual and can serve as legal evidence in court for both prosecuting and defending suspects. DNA fingerprinting plays a crucial role in uniquely identifying individuals. In cases of paternity, it can confirm or exclude individuals as the biological parents of a child. For example, the assassins Dhanu and Sivarasan, who were responsible for the murder of former Indian Prime Minister Rajiv Gandhi, were identified through DNA profiles. Despite its advancements, DNA fingerprinting has sparked ethical debates, such as whether individuals can be compelled to provide DNA samples and who should have access to this sensitive information. The creation of DNA databases also raises concerns about privacy and civil liberties, even though such databases might significantly aid genetic research. Scientists continue to explore new potential applications of DNA technology.

Introduction

The structure of DNA¹ (deoxyribonucleic acid) was first discovered by Dr. James Watson and Francis Crick in 1953. This foundational discovery has significantly impacted legal processes, helping to resolve many complex issues through DNA fingerprinting. When comparing DNA patterns between two unrelated individuals, the probability of a complete match is about 1 in 300 billion, which represents roughly half the global population.

DNA consists of four nitrogenous bases—adenine, thymine, cytosine, and guanine—along with a phosphoric acid, arranged in a regular structure. It is a polymer made up of nucleotides, the building blocks strung together to form a DNA strand. The backbone of each DNA strand is composed of a sugar component and a phosphate group. DNA molecules are organized into two strands coiled in a double helix formation.

DNA identification, which includes methods such as profiling, fingerprinting, and genotyping, involves analyzing specific, relatively rare features of an individual's genome. Every human, lower animal, and sexually reproduced plant has a unique hereditary composition, which results in a distinctive phenotype or physical appearance.

Procedure

In DNA typing², DNA extracted from samples such as blood, semen, or hair is fragmented using specific enzymes. These fragments are then separated into bands through gel electrophoresis. The DNA pattern is transferred to a nylon membrane, which is exposed to a radioactive probe, and an X-ray is taken. The resulting X-ray film reveals DNA bands, which are compared to those from a suspect. If the bands match, it confirms the individual's identity and establishes their connection to the sample. This technique allows

¹ DNA structure and function

Andrew Travers, Georgi Muskhelishvili, The FEBS journal 282 (12), 2279-2295, 2015

² An overview of DNA typing methods for human identification: past, present, and future

Robyn Thompson, Silvia Zoppis, Bruce McCord, DNA Electrophoresis Protocols for Forensic Genetics, 3-16, 2012



for precise identification, linking biological evidence like blood, semen, or hair found at a crime scene to a specific individual.

Contribution of DNA fingerprinting

The advancement of DNA fingerprinting has significantly improved the speed and accuracy of suspect identification in criminal investigations. For instance, blood found at a crime scene, which contains DNA in white blood cells (unlike red blood cells), can be analyzed to create a DNA fingerprint through electrophoresis. Criminals' DNA profiles are stored in databases, allowing for quick identification if they commit further crimes. However, crime scenes can contain multiple DNA sources, such as blood from the victim, hair from the perpetrator, or DNA from previous visitors. To ensure accurate results, forensic scientists must collect samples from the victim, suspects, and others who were present before the crime, while also taking measures to prevent contamination from law enforcement personnel. Defense attorneys may argue that contaminated DNA could affect the integrity of the evidence.

The role of forensic science in the justice system is crucial. The traditional methods of crime detection are becoming outdated, and DNA technology has introduced a new era in justice administration. DNA fingerprinting offers a precise method for identifying criminals and is applicable in both civil and criminal cases. It has largely replaced the need for eyewitness identification and has exonerated many innocent individuals, particularly in the USA, where DNA testing has overturned wrongful convictions and ensured that guilty parties are appropriately punished. Additionally, DNA fingerprinting has reduced delays in the justice system.

While traditional fingerprinting remains a useful tool, it is less reliable compared to DNA fingerprinting, especially since fingerprints are not always available at crime scenes and can be avoided by criminals using gloves. DNA fingerprinting provides a more dependable method of crime detection.

In the case of *Gangadharappa v. Basvaraj*, the plaintiff filed a suit against his father seeking partition and separate possession of his share in the Coparcenary properties. The defendant's father contested the claim, asserting that the plaintiff was not his biological child. Consequently, the defendant requested the appointment of a commissioner under Order 26 Rule 10-A of the Code of Civil Procedure and Section 151 to conduct blood and genetic fingerprint tests to verify the plaintiff's paternity. The plaintiff opposed this request on the grounds of Article 20(3) of the Constitution of India, which protects against self-

incrimination. Initially, the request for DNA fingerprinting was denied. However, upon revision, the High Court of Karnataka directed the appointment of a commissioner to conduct genetic fingerprint testing.

Impact of DNA fingerprinting

One of the most profound impacts of DNA fingerprinting has been in the realm of criminal justice. Prior to the advent of this technology, law enforcement relied heavily on eyewitness testimony, confessions, and traditional forms of evidence like fingerprints. However, these methods were not always reliable, leading to wrongful convictions and unsolved cases. DNA fingerprinting changed the landscape by providing a nearly infallible method for linking individuals to crime scenes.

The accuracy of DNA profiling³ has made it a cornerstone of modern forensic science. In criminal investigations, DNA evidence can be collected from a variety of sources, including blood, hair, skin cells, saliva, and other bodily fluids. When analyzed, this evidence can either implicate or exonerate suspects with a high degree of certainty. This has been particularly valuable in solving cold cases, where new DNA analysis techniques have been applied to old evidence, leading to the identification of perpetrators years, or even decades, after a crime was committed.

The reliability of DNA evidence has also led to its widespread acceptance in courts around the world. It is now considered one of the most compelling forms of evidence in criminal trials, often being the deciding factor in convictions. Moreover, DNA fingerprinting has been instrumental in overturning wrongful convictions. Organizations like the Innocence Project have used DNA evidence to exonerate individuals who were falsely imprisoned, highlighting the role of DNA profiling in ensuring justice is served.

Civil Law and Family Disputes

In addition to its impact on criminal justice⁴, DNA fingerprinting has played a crucial role in civil law, particularly in cases involving paternity and family disputes. Paternity testing, which determines whether

³ Accuracy and interlaboratory reliability of human papillomavirus DNA testing by hybrid capture

Mark H Schiffman, Nancy B Kiviat, Robert D Burk, Keerti V Shah, Richard W Daniel, Renee Lewis, Jane Kuypers, M Michele Manos, David R Scott, Mark E Sherman ,Journal of clinical microbiology 33 (3), 545-550, 1995

⁴ DNA in the Criminal Justice System: The DNA Success Story in Perspective,

Anna A Mapes, Ate D Kloosterman, Christianne J de Poot

a man is the biological father of a child, relies heavily on DNA profiling. The accuracy of DNA testing in paternity cases is nearly 100%, making it a trusted method for resolving disputes over child support, custody, and inheritance.

DNA fingerprinting has provided clarity and resolution in cases where paternity was in question, ensuring that legal responsibilities and rights are assigned correctly. This has had significant implications for child welfare, as accurate paternity determinations are critical for ensuring that children receive the financial and emotional support they need. Additionally, DNA testing has been used in immigration cases to prove familial relationships, further illustrating its impact on civil law.

Exoneration of the Wrongfully Convicted

One of the most celebrated contributions of DNA fingerprinting is its role in exonerating wrongfully convicted individuals. In many cases, people have been imprisoned for crimes they did not commit, often due to unreliable eyewitness testimony or coerced confessions. DNA evidence has provided a means to revisit these cases and establish the truth.

Since the 1990s, hundreds of people have been exonerated through DNA evidence, many of whom were on death row. This has not only brought justice to those wrongfully convicted but also highlighted the flaws in the criminal justice system. The exoneration of innocent individuals has sparked reforms aimed at preventing wrongful convictions, such as improving police procedures and ensuring that DNA evidence is collected and preserved properly.

Cold Case Solving

Another significant impact of DNA fingerprinting is its ability to solve cold cases—criminal investigations that have remained unsolved for years due to a lack of evidence or leads. As DNA technology has advanced, forensic scientists have revisited old cases with new tools, leading to the resolution of crimes that had long been considered unsolvable.

High-profile cases, such as the capture of the Golden State Killer in the United States, were solved through DNA evidence many years after the crimes were committed. In such cases, DNA from crime scenes was



compared to genetic profiles available in public databases, leading to the identification of suspects who had previously evaded justice. This ability to revisit and solve cold cases has provided closure to victims and their families, and has demonstrated the enduring value of DNA evidence in the pursuit of justice.

Advancements in Genetic Research

Beyond its applications in law enforcement and civil disputes, DNA fingerprinting has also significantly contributed to the field of genetic research. By enabling scientists to analyze and compare genetic material with precision, DNA fingerprinting has advanced our understanding of human genetics, heredity, and population diversity.

In medical research, DNA profiling has been used to identify genetic predispositions to diseases, track the inheritance of genetic disorders, and develop personalized medicine approaches. It has also been utilized in studies of human migration and ancestry, helping to uncover the historical movements and relationships of populations around the world. The insights gained from DNA research have had wide-ranging implications for public health, anthropology, and the study of human evolution.

Ethical and Privacy Concerns

Despite the numerous benefits of DNA fingerprinting, its widespread use has also raised important ethical and privacy concerns. One of the primary issues is the creation of DNA databases, where genetic profiles are stored for future reference. While these databases can be invaluable for solving crimes, they also raise questions about who should have access to such sensitive information and how it should be used.

There is a concern that DNA databases could be misused, leading to violations of privacy or discrimination based on genetic information. For example, there are fears that employers or insurance companies could use DNA data to make decisions about hiring or coverage, potentially discriminating against individuals with certain genetic traits. Additionally, the possibility of government surveillance through DNA tracking has sparked debates about civil liberties.

"Another ethical issue involves the collection of DNA samples. In criminal investigations, suspects may be required to provide DNA samples, raising questions about consent and the right to privacy. Moreover,



the use of DNA evidence in court has led to discussions about the potential for errors or contamination in DNA testing, which could lead to wrongful convictions if not properly handled"⁵.

Impact on Law and Legislation

The integration of DNA fingerprinting into legal systems has also influenced the development of laws and regulations. Governments and legal bodies have had to establish guidelines for the collection, storage, and use of DNA evidence to protect individuals' rights while ensuring that justice is served. These guidelines often address issues such as the retention of DNA profiles, access to DNA databases, and the use of DNA evidence in court.

In some countries, laws have been enacted to regulate the use of DNA evidence and ensure that it is collected and stored responsibly. For example, legislation may require that DNA samples be destroyed if a suspect is acquitted or not charged with a crime. Additionally, there are often legal frameworks in place to govern the admissibility of DNA evidence in court, ensuring that it meets certain standards of reliability and relevance.

In summary, DNA fingerprinting has had a transformative impact on multiple aspects of society. Its contributions to criminal justice have been particularly significant, providing a powerful tool for identifying perpetrators, solving cold cases, and exonerating the wrongfully convicted. In civil law, DNA profiling has resolved paternity disputes and clarified familial relationships, while in genetic research, it has advanced our understanding of human genetics and heredity.

However, the widespread use of DNA fingerprinting also raises important ethical and privacy concerns that must be carefully managed. As DNA technology continues to evolve, it will be essential to strike a balance between the benefits of DNA fingerprinting and the protection of individual rights. Overall, DNA fingerprinting stands as one of the most impactful scientific advancements of the modern era, with far-reaching implications for justice, science, and society.

⁵ Ancient DNA in anthropology: methods, applications, and ethics, Frederika A Kaestle, K Ann Horsburgh, American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists 119 (S35), 92-130, 2002

DNA Fingerprinting and Indian Law

While there is no specific law governing DNA tests in India, certain legal provisions address the use of DNA technology in the justice system. The evolving technology is gradually influencing the legal framework, as law is dynamic and must adapt to scientific advancements. DNA analysis plays a crucial role in civil disputes, particularly in determining paternity. This evidence is also significant in criminal cases, civil proceedings, and maintenance cases under Section 125 of the Code of Criminal Procedure, 1973. The Supreme Court's endorsement of a Delhi High Court judgment ordering Congress leader N.D. Tiwari to undergo a DNA test highlights the growing acceptance of DNA evidence in Indian courts.

The Indian Evidence Act, 1872, specifically Section 112, presumes legitimacy of a child born during a valid marriage unless proven otherwise. However, Indian courts are cautious about ordering DNA tests, as they may infringe on personal liberty and human rights. The Supreme Court's ruling in Gautam Kundu's case established guidelines against mandatory blood tests, emphasizing that such orders should not be issued casually.

Under Section 53 of the Code of Criminal Procedure, 1973, law enforcement can collect biological samples from a suspect for DNA testing. However, Indian courts are cautious about ordering such tests, considering the potential violation of constitutional rights. The case of Swati Lodha highlighted that DNA testing is not a violation of Article 20(3) of the Constitution, which protects against self-incrimination.

In 2011, the Delhi High Court issued a contempt notice to N.D. Tiwari for refusing to provide a blood sample for a DNA test in a paternity case. The conflict between the guidelines in Gautam Kundu's case and Section 53 of the Code of Criminal Procedure underscores the need for clarity in the law regarding DNA testing.

Conclusion

With advancements in science and technology, the methods of committing crimes have evolved. To combat these crimes effectively, outdated crime detection techniques are no longer sufficient. DNA fingerprinting has become an essential tool in crime detection and the administration of justice. While concerns about privacy exist, DNA technology offers numerous benefits, including its use in genetic studies, anthropology, and evolutionary research. To ensure justice is served, India's legal system must adapt and incorporate DNA technology into its framework, amending relevant laws as needed.evidence.



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