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REVIEW ARTICLE

DNA Evidence in Criminal Trials: Ensuring Accuracy and Preventing Misuse

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ABSTRACT

DNA evidence transformed forensic science by giving criminal trials an extremely precise method to connect people to crime scenes. DNA Profiling technology has made verdicts more dependable which results in effective prosecution and the release of innocent people who were previously convicted due to mishandling of the evidence. Though DNA evidence provides precise forensic results it retains inherent imperfections. Misinterpretation of results combined with sample contamination from improper conditions and collection errors can cause innocent people to be convicted which damages the credibility of the justice system. The research evaluated the scientific principles behind DNA evidence while analyzing how reliable forensic techniques are like Polymerase Chain Reaction (PCR) and Short Tandem Repeat (STR) analysis function alongside their respective limitations. The investigation assesses the role of DNA evidence within judicial processes while analyzing the admissibility standards including the Daubert Standard in the USA alongside Section 39 of the Bharatiya Sakshya Adhiniyam. DNA profiling has greatly improved criminal justice procedures although concerns about its improper application persist. The study presents an evaluation of wrongful convictions caused by flawed forensic analysis that stresses the importance of strong procedural rules alongside judicial expertise and ethical protections. The research indicates that regulatory frameworks must be established to maximize forensic DNA evidence benefits while minimizing related errors and privacy.

KEYWORDS

• DNA Evidence • DNA Profiling • Procedural guidelines • DNA evidence Regulatory framework • Privacy protection

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INTRODUCTION

DNA evidence now stands as a fundamental element in contemporary forensic investigations. DNA evidence earns its status as one of the most dependable forms of evidence since it remains unique to each individual except between identical twins. The expanding use of DNA evidence in legal proceedings triggers important discussions about its reliability as evidence and its potential for wrongful application. The forensic science field now relies on DNA profiling which began as genetic fingerprinting in the 1980s and has attained essential status for investigations. Investigations can now achieve higher accuracy in criminal cases by matching DNA samples from crime scenes with suspect profiles. The presence of DNA evidence in cases results in a large number of convictions. The growing use of DNA technology requires an evaluation of its dependability and possible drawbacks. DNA analysis begins with extracting genetic material from biological sources including blood samples, saliva, hair strands, or skin cells. Experts perform numerous tests to establish the distinct genetic profile of this material. Forensic scientists use the leading techniques for DNA analysis: Polymerase Chain Reaction (PCR) combined with Short Tandem Repeat (STR) analysis. Errors during sample collection or improper handling, contamination, and degradation can undermine DNA evidence reliability, resulting in incorrect legal outcomes. The rules regarding DNA evidence admission vary across legal systems globally. The Daubert Standard dictates how courts in the United States evaluate scientific evidence admissibility. The standard establishes that forensic evidence must demonstrate scientific validity and relevance to the case. Under Section 39 of Bharatiya Sakshya Adhiniyam, 2023, DNA evidence becomes admissible when expert testimony qualifies as legitimate evidence. Legal frameworks exist, but courts struggle to interpret DNA findings when statistical probabilities come into play. While DNA evidence provides accurate and legally admissible proof, it also raises ethical questions and challenges regarding privacy. These databases offer substantial assistance in solving unsolved cases and tracking habitual criminals yet they create major risks through unauthorized access and misuse which could lead to privacy violations. The use of familial DNA searches has sparked concerns because relatives of suspects might accidentally become subjects of investigations. Multiple legal cases have demonstrated the dual nature of DNA evidence by showing its strengths and limitations in criminal court cases. The 1997, R v. Dohney & Adams case demonstrated the critical role of statistical analysis in interpreting DNA evidence. People v. Wesley from 1988 represents a foundational moment in U.S. legal history as one of the earliest cases that accepted DNA evidence. The Santosh Kumar Singh v. State case from 2010 in India demonstrated DNA evidence's vital function in obtaining a conviction for Priyadarshini Mattoo. The State of Tennessee v. Ware case revealed DNA test vulnerabilities that resulted in wrongful accusations. DNA evidence maintains scientific strength but cannot guarantee absolute certainty. The potential for false positives, lab errors, and judicial misinterpretations demands strict protocols to ensure correct DNA evidence usage. The criminal justice system must find a middle ground between using DNA technology to improve judicial precision and protecting against its potential abuse.

SCIENTIFIC RELIABILITY OF DNA EVIDENCE

The underlying principle of DNA analysis is that no two individuals apart from identical twins share the same genetic code. The distinctive nature of DNA makes it an exceptionally dependable tool for forensic investigations. DNA profiling techniques have become much more accurate as technology has advanced. Forensic capabilities have improved significantly using Polymerase Chain Reaction (PCR) and Short Tandem Repeat (STR) analysis, the two most prevalent methods. The Polymerase Chain Reaction (PCR) technique enables scientists to enlarge minute DNA samples to become suitable for examination even if the material is degraded. Forensic experts can analyze traces of evidence including skin cells, saliva, or sweat through this process. PCR transformed DNA analysis by enabling scientists to analyze evidence samples, once deemed unusable. PCR amplification demands careful handling because minor contaminations can lead to inaccurate results. Short Tandem Repeat (STR) analysis represents a highly precise method used to study specific DNA regions that feature repeating patterns.

STR analysis achieves widespread use because its high discrimination power prevents two unrelated individuals from having identical DNA profiles. The FBI has adopted STR analysis as the foundational technique for CODIS which serves as a nationwide DNA database for criminal case investigations. Even though these methods are highly reliable DNA evidence can still face certain issues that may affect its validity. Evidence contamination stands as a significant problem that can happen anytime during the collection process or while transporting or analyzing the evidence in a laboratory. When DNA samples become contaminated with each other, it produces erroneous matches or incorrect findings. Environmental factors such as high temperatures, moisture levels, and sunlight exposure can cause DNA degradation which compromises genetic material integrity and leads to challenging analysis or unclear results. Another concern is the misinterpretation of DNA results. Forensic cases depend heavily on the statistical probability of DNA matches. A DNA match points toward someone's presence at a crime scene but it fails to prove their guilt beyond reasonable doubt. The validity of DNA evidence requires confirmation from additional forensic findings alongside witness statements and circumstantial evidence. The phenomenon of DNA secondary transfer has emerged as a significant problem in forensic science. DNA from an individual can end up on objects or people whom they have never interacted with through secondary transfer. False accusations emerge when individuals without direct contact with weapons or crime scenes are linked through DNA evidence found in these locations.

The reliability of DNA evidence depends on how well forensic laboratories perform their work. Wrongful convictions have resulted from forensic professionals receiving inadequate training and committing analysis biases or interpretation errors. The Houston Crime Lab Scandal demonstrated that forensic labs with poor management practices produced inaccurate DNA results which caused judicial errors. Forensic labs must implement strict quality control procedures along with blind testing and independent result verification to resolve existing problems. Standardized collection, storage, and analysis protocols are essential for enhancing DNA evidence reliability. Maintaining accurate chain-of-custody documentation is critical to guarantee evidence stays untampered. To avoid forensic data misinterpretation,courts need to confirm that DNA analysts possess proper qualifications and participate in ongoing training. DNA evidence stands as a critical investigative tool yet demands full compliance with forensic protocols and correct statistical analysis interpretation to remain dependable. The legal system must acknowledge DNA analysis's advantages and disadvantages to deliver fair justice.

LEGAL ADMISSIBILITY OF DNA EVIDENCE & LEADING JUDGEMENTS ON ACCURACY & IT'S MISUSE

The Daubert Standard serves as the primary determinant for DNA evidence admissibility across the U.S. courts. This standard establishes guidelines to determine which scientific evidence will be admitted in court based on its relevance and reliability. The Daubert Standard establishes that forensic evidence needs to fulfill certain benchmarks such as peer review status, error rate determination, and widespread scientific community acceptance. Judges examine if the procedures for creating DNA evidence meet established principles before they permit its use in legal proceedings. The landmark U.S. decision Kumho Tire Co. v. Carmichael expanded the Daubert Standard to cover expert testimony across all fields including forensic analysis. Frye v. United States 1923 established the Fyre Standard which mandated that scientific methods need to receive general acceptance from experts in the relevant field before being admissible. Under Section 39 of the Bharatiya Sakshya Adhiniyam, 2023, DNA evidence becomes admissible through expert testimony. The legal provision enables courts to evaluate forensic reports authored by scientific specialists such as DNA analysts. Several significant legal cases in India established important precedents for DNA evidence admissibility through their pivotal demonstration of its role. DNA evidence proved essential for the conviction of the accused in the Priyadarshini Mattoo rape and murder case. The Supreme Court of India recognized DNA evidence as definitive proof which highlighted the importance of forensic science in criminal court cases.

DNA profiling played a key role in connecting the accused to a rape and murder

case in State of Maharashtra v. Chandrabhan Sudam Sanap, 2015. The Supreme Court stated that DNA evidence possesses substantial significance in legal determinations of guilt or innocence when proper collection and analysis methods are followed. Although DNA evidence is admissible in court proceedings, courts continue to raise concerns about its reliability when facing cases of potential tampering and contamination. The Supreme Court highlighted improper forensic sample handling in Kishanbhai v. State of Gujarat, 2014, and urged for strict procedural safeguards to protect against judicial errors. In Surendra Koli v. State of Uttar Pradesh, 2011, a case involving DNA evidence from the Nithari killings investigation the defence argued that the evidence was unreliable because of improper chain-of-custody procedures, which could result in wrongful convictions. The case illustrated the vital need for law enforcement to follow forensic protocols precisely. Jurisdictions require DNA evidence to undergo stringent verification processes before it receives full judicial acceptance. The validity of forensic evidence depends on following proper procedures during collection, analysis, and courtroom presentation.

DNA databases alongside national forensic repositories such as the Combined DNA Index System (CODIS) in the U.S. have enabled more widespread use of DNA evidence. The potential misuse of genetic information together with data security and privacy concerns continue to create extensive legal and ethical challenges. Many legal systems have introduced strict rules governing DNA evidence to overcome these challenges. The Criminal Procedure Rules in the United Kingdom mandate strict quality assurance standards for DNA evidence which have been exemplified by the R v. Doheny & Adams, 1997, case that outlined how DNA statistics should be presented in court.

The utilization of DNA evidence in criminal trials has been significantly influenced by multiple landmark cases across various jurisdictions. R v. Doheny & Adams, 1997, stands as one of the United Kingdom's most influential cases because it highlighted the need for statistical analysis in DNA evidence presentation. The court established expert witness standards to guarantee that DNA evidence remains clear and non-misleading to the jury. This judicial decision established that a proper explanation of probability statistics is essential to avoid convicting individuals based only on DNA matches. People v. Wesley, 1988, became a landmark case in U.S. history for allowing DNA evidence to enter courtroom proceedings for the first time. The ruling determined that DNA profiling satisfied the Fyre Standard by demonstrating general acceptance among scientific experts. This case established DNA evidence as an essential element for both investigations and criminal trials throughout the U.S. The court determined that forensic evidence could be compromised through improper sample handling when they examined DNA result reliability. The judgment highlighted the essential requirement of preserving a proper chain of custody along with rigorous laboratory practices to avoid contamination and misinterpretation. The legal battle of Santosh Kumar Singh v. State, 2010, marked an essential turning point for DNA evidence acceptance in India. DNA analysis played a central role in the Supreme Court of India's decision to convict Santosh Kumar Singh for the rape and murder of Priyadarshini Mattoo which reversed his former acquittal. This case showed how the Indian judiciary started trusting DNA technology more while establishing its future acceptability in courtrooms. The Supreme Court ruling in the State of Maharashtra v. Chandrabhan SudamSanap, 2015, confirmed that DNA evidence is essential in criminal court proceedings. The forensic examination established a connection between the defendant and the crime scene which fortified the prosecution's case. The Supreme Court determined that DNA evidence which is collected and analyzed appropriately holds significant evidentiary value and strengthens its function in the judicial system. The Supreme Court's ruling in Anokhilal v. State of MP established DNA evidence as vital to preventing wrongful convictions through a decision grounded in scientific precision. The decision confirms the vital role forensic evidence plays in maintaining justice within the legal framework. Landmark legal decisions from different legal systems show how DNA evidence has evolved in criminal proceedings. The utilization of DNA technology to solve crimes gained judicial acknowledgment for its advantages but also drew attention to risks of contamination and the potential for misinterpretation and

procedural errors. Forensic jurisprudence depends on these legal case outcomes because they ensure DNA evidence is used properly and justly in the criminal justice system. The Innocence Project has used DNA evidence to free wrongly convicted persons but concerns about its misuse are still prevalent. The National Institute of Justice (NIJ) report from 2019 explains how forensic DNA analysis errors such as sample contamination and result misinterpretation have resulted in wrongful convictions. The report emphasizes the importance of implementing rigorous quality control and verification measures to maintain accurate results. False positive represents a significant problem when errors in lab operations incorrectly connect a crime scene to a person who did not commit the crime. Research from the National Academy of Sciences, 2009, reveals that forensic DNA evidence can be exaggerated during court proceedings which results in juries developing an unwarranted belief in its absolute accuracy. The absence of uniform protocols throughout forensic labs represents a significant issue. The President's Council of Advisors on Science and Technology's 2016 report identified multiple inconsistencies within forensic DNA analysis and advocated for better validation research to boost reliability. A debate has emerged because of the privacy concerns linked to DNA databases. DNA databases like CODIS in the U.S. and the UK's National DNA Database assist in solving crimes but they generate significant ethical concerns. According to a Human Rights Watch report, improper procedures for collecting and storing DNA samples risk evolving into a platform for mass surveillance and discriminatory practices. Forensic agencies need to implement rigorous handling protocols and provide ongoing training to forensic staff while supporting transparent court evaluations of DNA evidence before its courtroom use for misuse prevention. The criminal justice system must carefully manage the limitations and risks of DNA evidence to ensure power does not compromise fairness.

RECOMMENDATION AND CONCLUSION

Forensic evidence reliability and wrongful conviction prevention depend on standardized DNA collection and analysis methods. Report findings from the National Institute of Standards and Technology (NIST) reveal that flawed DNA collection and analysis processes produce substantial interpretation errors. Forensic professionals who apply uniform procedures for acquiring samples and analyzing them can reduce contamination risks while improving DNA evidence accuracy. Preventing miscarriage of justice requires judges and lawyers to understand DNA evidence's limitations and proper interpretation methods. The 2016 President's Council of Advisors on Science and Technology (PCAST) Report stated that judicial education in probabilistic reasoning and DNA statistical analysis is essential. Wrongful convictions can result from misinterpreted forensic evidence which demonstrates why judicial training programs must teach professionals to differentiate between scientifically sound forensic findings and overstated expert witness testimonies.

As national DNA registries expand the need to protect individual privacy rights results in growing ethical concerns about DNA databases. Human Rights Watch released a report, and the Electronic Frontier Foundation reported that genetic data misuse is dangerous when familial searching and indefinite DNA profile storage are employed. The implementation of precise guidelines about consent procedures and data storage duration along with third-party access limitations is essential to maintaining the advantages of DNA databases for law enforcement while ensuring basic privacy safeguards. The existence of independent verification mechanisms for DNA results prevents wrongful convictions in criminal cases that result from forensic mistakes such as sample mix-ups and result misinterpretations. Forensic agencies need to establish mandatory independent checks of DNA results to stop these wrongful convictions. Independent reviews of forensic outcomes strengthen credibility while minimizing trial and maintaining DNA evidence as a trustworthy instrument for justice.

The criminal justice system has transformed because DNA evidence provides dependable methods for convicting criminals and freeing innocent individuals. The scientific precision of DNA evidence to determine guilt or innocence renders it essential for contemporary forensic investigations. The reliability of DNA evidence depends entirely on the careful execution of its

collection and preservation processes together with precise analysis. Proper procedures for DNA evidence collection and analysis are vital since any breach has resulted in a significant miscarriage of justice exemplified by key cases in India and elsewhere. The Indian judicial system faces complex challenges in handling and interpreting DNA evidence. The Supreme Court in Ashok Kumar v. Raj Gupta & others, 2021, stated that DNA testing should not become standard practice because mandatory tests can violate people's fundamental privacy rights. The court maintained that DNA evidence should be employed solely when other significant proof lacks availability or remains inconclusive while underscoring the significance of judicial discretion. The approach maintains scientific accuracy while protecting constitutional rights through careful balance. The Supreme Court identified procedural failings in DNA evidence collection and processing in the case of Anokhilal v. State of MP, 2019. The court pointed out that although DNA evidence can greatly boost the prosecution's case, its value may be undermined by mishandling and procedural delays. The Court emphasized the importance of adhering to scientific protocols to ensure evidence integrity. The Punjab and Haryana High Court criticized investigative agencies in a 2024 rape case involving intellectually disabled minors for their inadequate collection of DNA evidence. The Court established strict guidelines to maintain forensic protocol adherence and warned that improper DNA sample management risks undermining justice. The court decision demonstrates judicial recognition of DNA evidence's vital importance in sensitive cases along with the requirement for strict procedural compliance. The Veerendra v. State of M.P., 2022, established that although DNA evidence carries significant weight in legal proceedings, its absence because of investigative errors does not directly result in acquittal. DNA results should be evaluated as part of a complete body of evidence instead of acting as the exclusive factor to determine innocence or guilt.

The credibility of DNA evidence requires the establishment of strong regulatory systems combined with strict evidence collection and analysis procedures. The justice system needs courts to enforce thorough inspections and independent assessments to remove human mistakes and maintain correct data readings. Forensic labs need to follow standardized procedures to prevent inconsistencies while a strict chain of custody ensures sample integrity. The criminal justice system cannot ignore DNA evidence because of its undeniable potential. The effectiveness of DNA analysis becomes questionable if samples are mishandled or conclusions are incorrectly drawn. Maintaining forensic process integrity demands strict safeguards along with continuous law enforcement training and judicial oversight. The justice system can effectively utilize DNA evidence as a key tool for truth while significantly reducing potential errors and injustices. Implementing these procedures will protect the scientific validity of DNA analysis and strengthen public trust in the criminal justice system's dedication to fair and precise case resolutions.

REFERENCES

1. Mukesh &Anr. V. State for NCT of Delhi &Ors., (2017) 6 SCC 1 (India)
2. Andrews v. State, 533 so. 2d 841 (Fla. Dist. Ct. App. 1988)
3. Rahul v. State of Delhi Ministry of Home Affairs &Anr., (2022) 9 SCR 1129 (India).
4. Alec Jeffreys, DNA *Profiling: The Pioneer's Perspective,* 354 Phil. Trans. R. Soc. Lond. B 5 (1999).
5. Itiel E. Dror & Greg Hampikian, *Subjectivity and Bias in Forensic DNA Mixture Interpretation,* 51 Sci. & Just. 204 (2011).
6. National Institute of Justice, DNA *Forensics: Expanding Uses and Information Sharing,* U.S. Dep't of Justice, NCJ 205475 (2005).
7. Kary B. Mullis, *The Unusual Origin of the Polymerase Chain Reaction,* 56 Sci. Am. 56 (1990).
8. John M. Butler, *Forensic DNA Typing: Biology, Technology, and Genetics of STR Markers* 147 (2d ed. 2005).
9. People v. Simpson, No. BA097211 (Cal. Super. Ct. Oct. 3, 1995).
10. Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579 (1993).
11. Bharatiya Sakshya Adhiniyam, Act No. 47 of 2023, § 39.
12. National Research Council, *The Evaluation of Forensic DNA Evidence* 192 (1996).
13. S and Marper v. United Kingdom, App. Nos. 30562/04 and 30566/04, 48 Eur. H.R. Rep. 50 (2008).

14. Forensic DNA Databases and Privacy Issues, Edinbox, https://edinbox.com/council/forensic-sciences-gfsec/2331-forensic-dna-databases-and-privacy-issues#:~:text=Despite%20their%20benefits%2C%20forensic%20DNA,%2C%20ancestry%2C%20and%20familial%2Dconnections (last visited Mar. 30, 2025).

15. Sonia M. Suter, All in the Family: Privacy and DNA Familial Searching, 23 Harv. J.L. & Tech. 309 (2010), available at http://jolt.law.harvard.edu/articles/pdf/v23/23HarvJLTech309.pdf.

16. Ankit Srivastava *et al.,* Impact of DNA Evidence in Criminal Justice System: Indian Legislative Perspectives, 12 *Egyptian Journal of Forensic Sciences* 51 (2022), available at https://ejfs.springeropen.com/articles/10.1186/s41935-022-00309-y.

17. *R v. Doheny & Adams*, [1996] EWCA Crim 728, [1997] 1 Cr. App. R. 369 (Court of Appeal), available at https://vlex.co.uk/vid/r-v-doheny-792775641

18. People v. Wesley, 83 N.Y.2d 417, 633 N.E.2d 451, 611 N.Y.S.2d 97 (1994), available at https://law.justia.com/cases/new-york/court-of-appeals/1994/83-n-y-2d-417-0.html

19. *Santosh Kumar Singh v. State through CBI,* (2010) 9 SCC 747, available at https://indiankanoon.org/doc/760449/.

20. Mitochondrial DNA, State of Tennessee v. Paul Ware, No. 103 (Tenn. Crim. App. 2001), available at https://www.promega.com/-/media/files/resources/profiles-in-dna/103/mitochondrial-dna-state-of-tennessee-v-paul-ware.pdf?la=en.

21. Jacob Kaplan, Shichun Ling & Maria Cuellar, Public Beliefs About the Accuracy and Importance of Forensic Evidence in the United States, 60 SCI. & JUST. 263, 263-72 (2020), https://doi.org/10.1016/j.scijus.2020.01.001.

22. Ate Kloosterman, Marjan Sjerps& Astrid Quak, Error Rates in Forensic DNA Analysis: Definition, Numbers, Impact and Communication, 12 Forensic Sci. Int'l: Genetics 77, 77-85 (2014), https://doi.org/10.1016/j.fsigen.2014.04.014.

23. Ray A. Wickenheiser, The Value of Forensic DNA Leads in Preventing Crime and Eliminating the Innocent, 3 Forensic Sci. Int'l: Synergy 100201, 100201 (2021), https://doi.org/10.1016/j.fsisyn.2021.100201

24. Forensic Science Simplified, Principles of DNA, https://www.forensicsciencesimplified.org/dna/principles.html#:~:text=Inside%20the%20nucleus%2C%20there%20are,have%20the%20same%20autosomal%20DNA (last visited Mar. 30, 2025).

25. National Center for Biotechnology Information, Introduction to Forensic DNA Analysis, https://www.ncbi.nlm.nih.gov/books/NBK232606/ (last visited Mar. 30, 2025).

26. J. Watherston, D. McNevin, M.E. Gahan, D. Bruce & J. Ward, Current and Emerging Tools for the Recovery of Genetic Information from Post Mortem Samples: New Directions for Disaster Victim Identification, 37 Forensic SCI. INT'L: Genetics 270, 270-82 (2018), https://doi.org/10.1016/j.fsigen.2018.08.016.

27. National Human Genome Research Institute, Polymerase Chain Reaction (PCR), https://www.genome.gov/genetics-glossary/Polymerase-Chain-Reaction-PCR (last visited Mar. 30, 2025).

28. J.M. Butler, Short Tandem Repeat Typing Technologies Used in Human Identity Testing, 43 Biotechniques Sii, Sii-Sv (2007), https://www.tandfonline.com/doi/full/10.2144/000112582.

29. Adrian Linacre, Duncan Taylor & Caitlin McDonald, A Comprehensive Review of DNA Barcoding Techniques, 15 Genes 438 (2024), https://doi.org/10.3390/genes15040438.

30. Ayush Chauhan, Types of PCR, FLABSLIS, https://flabslis.com/blogs/types-of-pcr (last visited Mar. 30, 2025).

31. M. Upadhyay, P. Shrivastava, K. Verma *et al.*, Recent Advancements in Identification and Detection of Saliva as Forensic Evidence: A Review, 13 Egypt J. Forensic Sci. 17 (2023), https://doi.org/10.1186/s41935-023-00336-3.

32. SK. Alketbi, Emerging Technologies in Forensic DNA Analysis, 1 Perspectives In Legal & Forensic Sci. 10007 (2024), https://doi.org/10.70322/plfs.2024.10007.

33. Nimrat Khehra, Inderbir S. Padda & Cathi J. Swift, Forensic Toxicology, https://www.ncbi.nlm.nih.gov/books/NBK589663/ (last visited Mar. 30, 2025).

34. Terry Taylor, What Is STR Analysis?, National Institute of Justice, https://nij.ojp.gov/topics/articles/what-str-analysis (last visited Mar. 30, 2025).

35. J. González-Bao *et al.*, Performance Comparison of a Previously Validated Microhaplotype

Panel and a Forensic STR Panel for DNA Mixture Analysis, 74 Forensic Sci. Int'l: Genetics 103144, 103144 (2025), https://doi.org/10.1016/j.fsigen.2024.103144.

36. FBI, CODIS, https://le.fbi.gov/science-and-lab/biometrics-and-fingerprints/codis-2 (last visited Mar. 30, 2025).

37. AZoLifeSciences, How Accurate is DNA Evidence?, https://www.azolifesciences.com/article/How-Accurate-is-DNA-Evidence.aspx#:~:text=Contamination%20and%20Sample%20Degradation,DNA%20samples%20collected%20before%20analysis (last visited Mar. 30, 2025).

38. Hayden B. Baldwin & Cheryl Puskarich May, Crime Scene Contamination Issues, Crime Scene Investigator, https://www.crime-scene-investigator.net/crime-scene-contamination-issues.html (last visited Mar. 30, 2025).

39. Ibid.

40. AZoLifeSciences, Reducing Contamination in Forensic Investigations, https://www.azolifesciences.com/article/Reducing-Contamination-in-Forensic-Investigations.aspx#:~:text=How%20does%20contamination%20occur?,being%20attributed%20to%20the%20exhibit (last visited Mar. 30, 2025).

41. Emmanuel Milot, Simon Baechler & Frank Crispino, Must the Random Man Be Unrelated? A Lingering Misconception in Forensic Genetics, 2 Forensic Sci. Int'l: Synergy 35, 35-40 (2020), https://doi.org/10.1016/j.fsisyn.2019.11.003.

42. Ibid.

43. Mondaq, The Role and Admissibility of Forensic Evidence in the Indian Criminal Justice System, https://www.mondaq.com/india/crime/1469694/the-role-and-admissibility-of-forensic-evidence-in-the-indian-criminal-justice-system (last visited Mar. 30, 2025).

44. Francesco Sessa, Cristoforo Pomara, Massimiliano Esposito, Patrizia Grassi, Giuseppe Cocimano& Monica Salerno, https://pmc.ncbi.nlm.nih.gov/articles/PMC10742555/ (last visited Mar. 30, 2025).

45. Ibid.

46. National Institute of Justice, Wrongful Convictions and DNA Exonerations: Understanding the Role of Forensic Science, https://nij.ojp.gov/topics/articles/wrongful-convictions-and-dna-exonerations-understanding-role-forensic-science (last visited Mar. 30, 2025).

47. Australian Law Reform Commission, Reliability of DNA Evidence, in Essentially Yours: The Protection of Human Genetic Information In Australia, Alrc Report 96, https://www.alrc.gov.au/publication/essentially-yours-the-protection-of-human-genetic-information-in-australia-alrc-report-96/44-criminal-proceedings/reliability-of-dna-evidence/ (last visited Mar. 30, 2025).

48. John Morgan, Wrongful Convictions and Claims of False or Misleading Forensic Evidence, https://onlinelibrary.wiley.com/doi/10.1111/1556-4029.15233 (last visited Mar. 30, 2025).

49. Proceedings of the National Academy of Sciences, https://www.pnas.org/doi/10.1073/pnas.2303592120 (last visited Mar. 30, 2025).

50. National Center for Biotechnology Information, https://www.ncbi.nlm.nih.gov/books/NBK232602/ (last visited Mar. 30, 2025).

51. Dr. Pratibha Tiwari, Challenges and Solutions in DNA Fingerprinting: Sample Quality, Data Analysis, and Interpretation, https://www.biochemjournal.com/archives/2024/vol8issue1/PartD/8-1-85-113.pdf (last visited Mar. 30, 2025).

52. Ashish Badiye, Neeti Kapoor & Ritesh G. Menezes, The Chain of Custody in Forensic Science, https://www.ncbi.nlm.nih.gov/books/NBK551677/#:~:text=The%20chain%20of%20custody%20is,custody%20or%20chain%20of%20evidence (last visited Mar. 30, 2025).

53. Eva AluvaalaNambati *et al.*, Multidisciplinary Approach Towards Training of the Next Generation of Forensic DNA Analysts in Africa: A Kenyan Perspective, 2 Forensic Sci. Int'l: Synergy 123, 123-25 (2020), https://doi.org/10.1016/j.fsisyn.2020.03.003.

54. National Institute of Standards and Technology, https://nvlpubs.nist.gov/nistpubs/ir/2024/NIST.IR.8503.pdf (last visited Mar. 30, 2025).

55. Grette Titus, The Role and Importance of DNA Evidence in the Indian Criminal Justice System, 17 Indian J. Forensic Med. & Toxicology 30, 30-35 (2023), https://www.researchgate.net/publication/377560476_The_Role_and_Importance_of_DNA_Evidence_in_the_Indian_Criminal_Justice_System/citation/download.

56. Legal Information Institute, Daubert Standard, Cornell Law School, https://www.law.cornell.edu/wex/daubert_standard (last visited Mar.

30, 2025).

57. Ibid.

58. Faro, Daubert in Detail, https://www.faro.com/en/Resource-Library/Article/Daubert-in-Detail (last visited Mar. 30, 2025).

59. Patrons Legal, DNA Profiling in Civil and Criminal Matters: Constitutional Aspects, https://patronslegal.com/blogs/dna-profiling-in-civil-and-criminal-matters-constitutional-aspects/#:~:text=POSITION%20IN%20INDIA:,21%20of%20the%20Constitution (last visited Mar. 30, 2025).

60. Casemine, Kumho Tirev. Carmichael: Extending Daubert's Reliability Standards to Technical and Specialized Testimony, https://www.casemine.com/commentary/us/kumho-tire-v.-carmichael:-extending-daubert's-reliability-standards-to-technical-and-specialized-testimony/view#:~:text=This%20has%20profound%20implications%20for%20various%20fields%2C,disciplines%2C%20as%20it%20mandates%20that%20all%20expert (last visited Mar. 30, 2025).

61. Anjelica Cappellino, Admitting Expert Testimony Under the Frye Standard: The Ultimate Guide, https://www.expertinstitute.com/resources/insights/admitting-expert-testimony-under-the-frye-standard-the-ultimate-guide/ (last visited Mar. 30, 2025).

62. Jeevan Shekar, The Admissibility of Scientific Evidence in Bharatiya Sakshya Adhiniyam, 2023 and the Need for an Indian Daubert, SSRN (Aug. 11, 2024), https://ssrn.com/abstract=5052611.

63. Ibid.

64. Chatrapal Singh, DNA Technology in Criminal Investigation in India, J. Emerging Techs. & Innovative Research, Sept. 2024, at 719, available at https://www.jetir.org/papers/JETIR2409382.pdf.

65. Nidhi N. Anand, Media Trial in India and Case Analysis of Priyadarshini Mattoo Case with Respect to Media Trial, Indian J. Integrated Research in Law, May 2022, at 1, available at https://ijirl.com/wp-content/uploads/2022/05/Media-Trial-In-India-And-Case-Analysis-Of-Priyadarshini-Mattoo-Case-With-Respect-To-Media-Trial.pdf.

66. Chandrabhan SudamSanap v. State of Maharashtra, Crim. App. No. 879 of 2019 (Supreme Court of India Jan. 28, 2025), available at https://www.sci.gov.in/sci-get-pdf/?diary_no=133162019&type=j&order_date=2025-01-28&from=latest_judgements_order.

67. Appeal No. 1111 of 2015, High Court of Judicature at Bombay, Dec. 20, 2018, available at https://www.shadesofknife.in/wp-content/uploads/2018/12/The-State-of-Maharastra-Vs-Chandrabhan-Sudam-Snap-on-20-December-2018.pdf.

68. National Research Council (US) Committee on DNA Forensic Science: An Update, *The Evaluation of Forensic DNA Evidence* (National Academies Press 1996), available at https://www.ncbi.nlm.nih.gov/books/NBK232607/.

69. State of Gujarat v. Kishanbhai, (2014) 1 SCC 108, available at https://indiankanoon.org/doc/24057125/.

70. Surendra Koli v. State of Uttar Pradesh, (2011) 4 SCC 80, available at https://indiankanoon.org/doc/659859/.

71. Ibid.

72. Dr. Himanshu Pandey & Ms. Anhita Tiwari, *Evidential Value of DNA: A Judicial Approach,* Bharati Law Review, Jan.–Mar. 2017, available at https://docs.manupatra.in/newsline/articles/upload/bf936e7d-4211-4ae4-9bd7-3d721a8e424c.pdf.

73. Shichun Ling, Jacob Kaplan & Colleen M. Berryessa, The Importance of Forensic Evidence for Decisions on Criminal Guilt, *Science & Justice,* 61(2):142–149 (2021), https://doi.org/10.1016/j.scijus.2020.11.004.

74. Angi M. Christensen, Nicholas V. Passalacqua & Eric J. Bartelink, Chapter 14: Personal Identification, in *Forensic Anthropology* 443–68 (Angi M. Christensen *et al.* eds., 2d ed. 2019), available at https://doi.org/10.1016/B978-0-12-815734-3.00014-2.

75. Nicole Martinez-Martin & David Magnus, Privacy and Ethical Challenges in Next-Generation Sequencing, *Expert Review of Precision Medicine and Drug Development,* 4(2):95–104 (2019), available at https://doi.org/10.1080/23808993.2019.1599685.:contentReference[oaicite:2]{index=2}

76. Sunil K. Verma & Gajendra K. Goswami, DNA Evidence: Current Perspective and Future Challenges in India, *Forensic Science International,* 241:183–189 (2014), https://doi.org/10.1016/j.forsciint.2014.05.016.

77. Paul Roberts, LTDNA Evidence on Trial, *Frontiers in Genetics,* 7:180 (2016), available at https://doi.org/10.3389/fgene.2016.00180 (accessed Mar. 31, 2025).

78. Srivastava, A., Harshey, A., Das, T., *et al*., Impact of DNA Evidence in Criminal Justice System: Indian Legislative Perspectives, *Egyptian Journal of Forensic Sciences*, 12:51 (2022), available at https://doi.org/10.1186/s41935-022-00309-y.

79. R v. Doheny & Adams, [1997] 1 Cr. App. R. 369 (Eng. Crim. App.), available at https://vlex.co.uk/vid/r-v-doheny-792775641.

80. Ibid.

81. Ibid.

82. Denise A. Filocoma, Unravelling the DNA Controversy: *People v. Wesley,* a Step in the Right Direction, 3 J.L. &Pol'y 351 (1995), available at https://brooklynworks.brooklaw.edu/jlp/vol3/iss2/8.

83. Ibid.

84. Ibid.

85. Australian Law Reform Commission, *Essentially Yours: The Protection of Human Genetic Information in Australia* (ALRC Report 96), Chapter 44: Criminal Proceedings, available at https://www.alrc.gov.au/publication/essentially-yours-the-protection-of-human-genetic-information-in-australia-alrc-report-96/44-criminal-proceedings/reliability-of-dna-evidence/.

86. Ibid.

87. Santosh Kumar Singh v. State Through CBI, (2010) 2 SCC 44, available at https://www.casemine.com/judgement/in/5609aeece4b014971141529e.

88. Ibid.

89. Ibid.

90. Ramprakash Rajagopal, Electronic Records Objection: Though Objection Regarding Absence of Certificate Under Section 65B IEA Not Raised While Marking, Question Put to the Witness Is Treated as Objection, *Section1.in* (Feb. 3, 2025), available at https://section1.in/electronic-records-objection-though-objection-regarding-absence-of-certificate-under-section-65b-iea-not-raised-while-marking-but-question-put-to-the-witness-is-treated-as-objection/

91. Ibid.

92. Anokhilal v. State of Madhya Pradesh, Criminal Appeal Nos. 62-63 of 2014, Supreme Court of India, judgment dated December 18, 2019, available at https://api.sci.gov.in/supremecourt/2013/25955/25955_2013_6_1501_19251_Judgement_18-Dec-2019.pdf.

93. Ibid.

94. Singh, S.C., DNA Profiling and the Forensic Use of DNA Evidence in Criminal Proceedings, *Journal of the Indian Law Institute,* 53(2): 195–226 (2011), available at http://www.jstor.org/stable/43953503.

95. Karen Norrgard, Forensics, DNA Fingerprinting, and CODIS, *Nature Education*, 1(1):35 (2008), available at https://www.nature.com/scitable/topicpage/forensics-dna-fingerprinting-and-codis-736/#:~:text=DNA%20evidence%20is%20used%20in,kinds%20of%20crime%20scene%20evidence.

96. Daniele Selby, DNA and Wrongful Conviction: Five Facts You Should Know, *Innocence Project* (Apr. 25, 2023), available at https://innocenceproject.org/news/dna-and-wrongful-conviction-five-facts-you-should-know/.

97. National Institute of Justice, The Impact of False or Misleading Forensic Evidence on Wrongful Convictions, *National Institute of Justice* (Nov. 28, 2023), available at https://nij.ojp.gov/topics/articles/impact-false-or-misleading-forensic-evidence-wrongful-convictions.

98. Ibid.

99. Ibid.

100. Erin E. Murphy, What 'Strengthening Forensic Science' Today Means for Tomorrow: DNA Exceptionalism and the 2009 NAS Report, *Law, Probability* & Risk, 9(1): 7–22 (2010), available at https://academic.oup.com/lpr/article/9/1/7/949818.

101. Srishti, The Impact of Forensic Science on the Legal System in India, *Journal of Forensic Science and Research,* 9(1): 1–6 (2025), available at https://doi.org/10.29328/journal.jfsr.1001072.

102. President's Council of Advisors on Science and Technology, *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods* (Sept. 2016), available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf.

103. H.M. Wallace, A.R. Jackson, J. Gruber & A.D. Thibedeau, *Forensic DNA Databases–Ethical and Legal Standards: A Global Review, Egyptian Journal of Forensic Sciences,* 4(3):57–63 (2014), available at https://doi.org/10.1016/j.ejfs.2014.04.002.

104. Aziza Ahmed, Ethical Concerns of DNA Databases Used for Crime Control, *Petrie-Flom Center* (Jan. 14, 2019), available at https://petrieflom.law.harvard.edu/2019/01/14/ethical-concerns-of-dna-databases-used-for-

crime-control/.

105. Human Rights Watch, *Dismantling Detention: International Alternatives to Detaining Immigrants* (Nov. 3, 2021), available at https://www.hrw.org/report/2021/11/03/dismantling-detention/international-alternatives-detaining-immigrants.

106. Jonathan J. Koehler, Jennifer L. Mnookin & Michael J. Saks, The Scientific Reinvention of Forensic Science, *Proceedings of the National Academy of Sciences,* 120(41):e2301840120 (2023), available at https://doi.org/10.1073/pnas.2301840120.

107. Joe Smith &Mogambal Singh, Forensic DNA Profiling: Legal and Ethical Considerations, *Journal of Scientific Research and Rep*orts, 30:141–44 (2024), available at https://doi.org/10.9734/jsrr/2024/v30i51929.

108. S. Panneerchelvam& M.N. Norazmi, Forensic DNA Profiling and Database, *Malaysian Journal of Medical Sciences,* 10(2):20–26 (2003), available at https://pubmed.ncbi.nlm.nih.gov/23386793/.

109. John M. Butler, Hari Iyer, Rich Press, Melissa K. Taylor, Peter M. Vallone & Sheila Willis, *DNA Mixture Interpretation: A NIST Scientific Foundation Review,* NIST Interagency Report (IR) 8351 (Dec. 2024), available at https://nvlpubs.nist.gov/nistpubs/ir/2024/NIST.IR.8351.pdf.

110. Salem Khalifa Alketbi, DNA Contamination in Crime Scene Investigations: Common Errors, Best Practices, and Insights from a Survey Study, Biomed Journal of Scientific & Technical Research, 58(5):50970–50977 (2024), available at https://biomedres.us/pdfs/BJSTR.MS.ID.009223.pdf.

111. Shichun Ling, Jacob Kaplan & Colleen M. Berryessa, The Importance of Forensic Evidence for Decisions on Criminal Guilt, *Science & Justice,* 61(2):142–149 (2021), available at https://doi.org/10.1016/j.scijus.2020.11.004.

112. President's Council of Advisors on Science and Technology, *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods* (Sept. 2016), available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf.

113. National Institute of Justice, The Impact of False or Misleading Forensic Evidence on Wrongful Convictions, *National Institute of Justice* (Nov. 28, 2023), available at https://nij.ojp.gov/topics/articles/impact-false-or-misleading-forensic-evidence-wrongful-convictions.

114. Ray A. Wickenheiser, Expanding DNA Database Effectiveness, *Forensic Science International: Synergy,* 4:100226 (2022), available at https://doi.org/10.1016/j.fsisyn.2022.100226.

115. Human Rights Watch, *China: Minority Region Collects DNA from Millions* (Feb. 18, 2025), https://www.hrw.org/news/2017/12/13/china-minority-region-collects-dna-millions.

116. Institute of Medicine (US) Committee on Regional Health Data Networks, Confidentiality and Privacy of Personal Data, *in Health Data in the Information Age: Use, Disclosure, and Privacy* (M.S. Donaldson & K.N. Lohr eds., National Academies Press 1994), available at https://www.ncbi.nlm.nih.gov/books/NBK236546/#:~:text=Rerelease%20to%20Third%20Parties%20Without,purpose%20or%20a%20compatible%20one.&text=An%20especially%20troublesome%20problem%2-0is,employer%20and%20a%20potential%20employer).

117. William C. Thompson, The Potential for Error in Forensic DNA Testing (and How That Complicates the Use of DNA Databases for Criminal Identification), in *Genetic Explanations: Sense and Nonsense* (Sheldon Krimsky & Jeremy Gruber eds., Harvard University Press 2013), available at https://www.researchgate.net/publication/242076707_The_Potential_for_Error_in_Forensic_DNA_Testing_and_How_That_Complicates_the_Use_of_DNA_Databases_for_Criminal_Identification.

118. Kathane, Prachi, Singh, Anshu, Gaur, J.R., & Krishan, Kewal. The Development, Status and Future of Forensics in India, Forensic Science International: Reports, 3, Article 100215 (2021), available at https://doi.org/10.1016/j.fsir.2021.100215.

119. Jonathan J. Koehler, Jennifer L. Mnookin, & Michael J. Saks, The Scientific Reinvention of Forensic Science, *Proceedings of the National Academy of Sciences,* 120(41): e2301840120 (2023), available at https://doi.org/10.1073/pnas.2301840120.

120. Rakesh Kumar Singh, Justice through DNA Technology, *UJALA: Judicial and Legal Review*, Vol. 4, Article 4 (2025), available at https://ujala.uk.gov.in/files/Vol%204/Article_4.pdf.

121. Dr. Himanshu Pandey & Ms. Anhita Tiwari, Evidential Value of DNA: A Judicial Approach, *Bharati Law Review,* Jan.–Mar. 2017, at 13–35, available at https://docs.manupatra.

in/newsline/articles/upload/bf936e7d-4211-4ae4-9bd7-3d721a8e424c.pdf

122. Aaratrika Bhaumik, Supreme Court Monthly Digest: October 2021 [Citation: LL 2021 SC 525 To LL 2021 SC 616], *Live Law* (Dec. 22, 2021), available at https://www.livelaw.in/top-stories/supreme-court-news-october-2021-digest-with-citations-188197.

123. Ibid.

124. Anokhilal v. State of Madhya Pradesh, (2019) 20 SCC 225.

125. Aiman J. Chishti, Punjab & Haryana High Court Flags 'Lackadaisical Approach' of Police in Collecting DNA, Seeks Affidavit of DGP on Compliance of Guidelines, *Live Law* (May 30, 2024), available at https://www.livelaw.in/high-court/punjab-and-haryana-high-court/punjab-haryana-high-court-flags-lackadaisical-approach-of-police-in-collecting-dna-seeks-affidavit-of-dgp-punjab-haryana-chandigarh-on-compliance-of-guidelines-rape-of-minor-disabled-girl-259218.

126. Veerendra v. State of Madhya Pradesh, Criminal Appeal No. 39/2015, Supreme Court of India, judgment dated July 14, 2016, available at https://theamikusqriae.com/veerendra-v-state-of-madhya-pradesh/.