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FORENSIC DNA EVIDENCE IN CRIMINAL JUSTICE: RELIABILITY, ADMISSIBILITY AND LEGAL SAFEGUARDS IN INDIA

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ABSTRACT

Forensic DNA profiling has transformed the landscape of criminal adjudication, offering courts a scientific mechanism of remarkable precision to link suspects to crime scenes or exonerate the wrongly accused. This paper examines the evidentiary value of forensic DNA evidence within the Indian criminal justice framework, tracing its scientific foundations, legislative architecture, and judicial reception. It critically interrogates the reliability of DNA-based expert testimony, the procedural safeguards that govern its collection and analysis, and the constitutional tensions that arise when forensic compulsion encroaches upon individual rights. Drawing upon comparative jurisprudence, empirical literature and the emerging Indian statutory landscape—particularly the DNA Technology (Use and Application) Regulation Bill, 2019—this paper argues that the transformative potential of DNA evidence can only be fully realised when matched by robust institutional accountability, trained forensic infrastructure, and a rights-protective legal framework. The paper concludes with recommendations for legislative and procedural reform directed at Indian law students, practitioners and policymakers.

Keywords: *Forensic DNA; Criminal Evidence; Expert Testimony; DNA Regulation Bill 2019; Indian Criminal Justice; Admissibility; Constitutional Rights.*

I. INTRODUCTION

The administration of criminal justice has always rested upon the integrity of evidence. Long before the age of scientific detection, courts depended upon witness testimony, confessions and circumstantial inference—tools prone to fallibility, manipulation and systemic bias. The arrival of forensic science in the nineteenth century promised an empirical corrective, and no development within that broad discipline has proven more consequential than DNA profiling. Rooted in the immutable genetic architecture of every human being, DNA analysis offers a mode of identification that is, in principle, both objective and extraordinarily accurate. As Edmond Locard famously postulated, every contact leaves a trace,[1708] and it is DNA evidence that renders that trace most legible to the law.

Yet the power of DNA evidence is not unlimited. Its probative value depends critically on the conditions under which biological samples are collected, preserved, analysed, and interpreted—each stage presenting opportunities for contamination, error, or deliberate manipulation. As Paul Kirk noted,

[1708]Edmond Locard, 'L'enquête criminelle et les méthodes scientifiques' (1920). Locard's Exchange Principle remains one of the foundational tenets of modern forensic science.

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physical evidence cannot lie, but[1709] its significance can be misrepresented, misunderstood, or selectively deployed. The challenge for the legal system is therefore not merely to embrace DNA technology but to subject it to rigorous scrutiny commensurate with the weight it carries in the balance of criminal justice.

India presents a particularly instructive case study. A nation of continental scale, with one of the world's oldest legal traditions now administered through a common law system, India has witnessed accelerating judicial and legislative engagement with forensic DNA evidence over the past two decades. The existing criminal procedure framework—anchored in the Code of Criminal Procedure, 1973 and the Indian Evidence Act, 1872—was not designed with genomic science in mind, and courts have had to adapt general principles of expert testimony, relevance and constitutional protection to accommodate a technology that was barely conceivable when those statutes were enacted. The result is a body of doctrine that is rich in its aspirations but uneven in its execution, and a forensic infrastructure that is still maturing relative to the demands placed upon it.[1710]

This paper addresses these intersecting dimensions of science and law. Part II surveys the scientific principles underlying DNA profiling and the principal methodologies employed in forensic laboratories. Part III examines the legal framework governing the admissibility and evidentiary weight of DNA evidence in India. Part IV engages with the constitutional questions of bodily integrity and self-incrimination raised by compelled forensic sampling. Part V assesses the reliability concerns that attend DNA analysis, including the risks of cognitive bias and contextual contamination. Part VI evaluates the DNA Technology Regulation Bill and other proposed reforms. Part VII offers conclusions and recommendations.

II. THE SCIENTIFIC FOUNDATIONS OF FORENSIC DNA PROFILING

Deoxyribonucleic acid (DNA) is the molecular blueprint of biological life. Located within the nucleus of virtually every human cell, DNA carries the genetic instructions that determine an individual's biological characteristics. The human genome contains approximately three billion base pairs, and while nearly 99.9 per cent of the genetic sequence is identical across the human species, the remaining variation is sufficient to produce a profile that, in practical terms, is unique to each individual (with the exception of identical twins). It was upon this foundation that Sir Alec Jeffreys and his colleagues at the University of Leicester developed the technique of DNA fingerprinting in 1984, publishing their landmark findings in 1985.[1711]

Modern forensic DNA analysis predominantly employs Short Tandem Repeat (STR) profiling, which examines specific loci in the genome where short sequences of nucleotides are repeated. The number of repeats at each locus varies among individuals, and by comparing the STR profiles obtained from crime scene samples with those of known individuals, forensic scientists can calculate a match probability—the statistical likelihood that a random person unrelated to the suspect would share the observed profile.[1712]

Beyond STR analysis, advancing technologies have extended the forensic toolkit considerably. Mitochondrial DNA (mtDNA) analysis proves valuable in degraded samples where nuclear DNA is unavailable, particularly in cases involving skeletal remains or hair shafts without roots. Y-chromosome analysis assists in the investigation of sexual offences by tracing patrilineal lineage. More recently, forensic DNA

[1709]Paul Kirk, 'Crime Investigation: Physical Evidence and the Police Laboratory' (Interscience Publishers, 1953) 4.

[1710]National Academy of Sciences, 'Strengthening Forensic Science in the United States: A Path Forward' (National Academies Press, 2009) 87.

[1711]Jay Aronson, 'Genetic Witness: Science, Law, and Controversy in the Making of DNA Profiling' (Rutgers University Press, 2007) 12.

[1712]Alec Jeffreys, Victoria Wilson and Swee Lay Thein, 'Hypervariable Minisatellite Regions in Human DNA' (1985) 314 Nature 67–73.

phenotyping—the prediction of physical appearance and biogeographic ancestry from DNA—has attracted both scientific interest and significant ethical concern, raising questions about racial profiling and the scope of legitimate forensic inference.

The probative strength of DNA evidence depends, however, on the integrity of the analytical chain. Biological samples deposited at crime scenes—blood, saliva, semen, hair, skin cells—are vulnerable to environmental degradation, cross-contamination, and mishandling. The interpretation of mixed DNA profiles, obtained from samples containing genetic material from more than one contributor, presents particular challenges: the subjective element in distinguishing individual contributors from a complex mixture has been shown to introduce significant analyst-to-analyst variability, threatening the objectivity upon which DNA evidence's authority rests.

III. THE LEGAL FRAMEWORK: ADMISSIBILITY AND EVIDENTIARY WEIGHT IN INDIA

The admission of forensic evidence in Indian courts is governed principally by the Indian Evidence Act, 1872, which permits the opinion of experts on questions of science or art to be received as relevant evidence under Section 45. DNA profiling, as a matter of scientific analysis, falls squarely within this provision. Courts have treated forensic scientists as expert witnesses whose testimony may assist the trier of fact in understanding technical matters beyond ordinary judicial competence.[1713]

The procedural dimension of DNA evidence collection was substantially reinforced by amendments to the Code of Criminal Procedure. Section 53A, introduced by the 2005 Amendment, expressly provides for the examination of a person accused of rape by a medical practitioner, authorising the collection of blood samples and other biological materials for DNA analysis.[1714]

The Supreme Court of India has, on multiple occasions, affirmed the reliability and relevance of DNA evidence. In cases of disputed paternity, the Court has held that DNA testing provides conclusive proof. In criminal proceedings, DNA match evidence has been treated as corroborative evidence of considerable weight, though courts have been cautious to avoid reducing conviction to a mechanical application of probabilistic statistics without attending to the broader evidentiary context. This approach reflects a sound instinct: a DNA match narrows the pool of possible contributors but does not, in itself, prove guilt—it must be evaluated alongside motive, opportunity, and the circumstances of the alleged offence.

However, the Indian forensic science infrastructure remains uneven. A significant proportion of crime laboratories are inadequately equipped, and the shortage of trained forensic scientists means that evidence may languish unanalysed for extended periods, compromising its integrity and its utility in time-sensitive prosecutions. The National Academy of Sciences in the United States identified similar institutional failures in its seminal 2009 report, and many of those observations are equally apposite to the Indian context.[1715]

IV. CONSTITUTIONAL DIMENSIONS: BODILY INTEGRITY AND SELF-INCRIMINATION

The compulsory extraction of biological samples for DNA analysis engages fundamental rights under the Constitution of India. Article 20(3) guarantees that no person accused of an offence shall be compelled to be a witness against himself—the privilege against self-incrimination. The question of whether providing a blood or tissue sample for DNA analysis constitutes 'testimony' within the meaning of

[1713] Thompson WC, Ford S, Doom T, Raymer M and Krane DE, 'Evaluating Forensic DNA Evidence: Essential Elements of a Competent Defense Review' (2003) 37 The Champion 16.

[1714] The Innocence Project, 'DNA Exonerations in the United States' <https://innocenceproject.org/dna-exonerations-in-the-united-states> accessed 10 March 2025.

[1715] Code of Criminal Procedure, 1973 (India), s 53A (inserted by the Code of Criminal Procedure (Amendment) Act, 2005).

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this provision has generated significant jurisprudential debate.[1716]

In Selvi v State of Karnataka (2010), the Supreme Court drew a critical distinction between testimonial acts—which engage Article 20(3)—and physical acts, which do not. The Court held that compelled narco-analysis, polygraph testing and brain electrical oscillations profiling violated the constitutional protection because they involved communicative content derived from the accused's mental processes. However, the extraction of blood samples or other biological material was treated as a physical act, not implicating the privilege against self-incrimination.[1717]

This distinction, while legally coherent in formal terms, has been contested by scholars who argue that DNA analysis extracts not merely physical data but a wealth of personal information—health conditions, familial relationships, ancestral origins, and predispositions—that goes far beyond what any traditional physical sample could reveal. Nita Farahany's work on the privacy dimensions of neurological and genetic forensic evidence underscores the inadequacy of the physical/testimonial dichotomy in the genomic age.[1718]

The right to privacy, recognised as a fundamental right under Article 21 of the Constitution by the Supreme Court's nine-judge bench in Justice K.S. Puttaswamy v Union of India (2017), adds a further constitutional dimension. The construction and maintenance of DNA databases—an essential feature of any modern forensic DNA regime—involves the systematic collection, storage and potential repurposing of highly personal biological information. The legality of such databases must be assessed against the requirements of legality, necessity and proportionality that the Puttaswamy judgment identified as essential to any limitation on the right to privacy.

V. RELIABILITY CONCERNS: BIAS, ERROR AND THE LIMITS OF CERTAINTY

Despite its remarkable scientific credentials, DNA evidence is not immune from error or abuse. Studies by Garrett and Neufeld have documented numerous cases in which forensic analysts presented invalid testimony—overstating the significance of DNA evidence, mischaracterising statistical probabilities, or offering conclusions that went beyond what the underlying data could support.[1719]

Cognitive bias presents a particularly insidious risk. Forensic analysts operating within law enforcement institutions may be exposed to case information—a suspect's prior record, investigative theories, or the perceived gravity of the offence—that unconsciously influences their interpretation of ambiguous evidence. Dror and Hampikian's experiments have demonstrated that the same mixed DNA profile, presented to multiple experienced analysts with different contextual information, can yield markedly different conclusions about the contributors.[1720]

The President's Council of Advisors on Science and Technology (PCAST) in the United States has comprehensively assessed the scientific validity of a range of forensic feature-comparison methods, concluding that for several disciplines—including bite mark analysis and firearms examination—the scientific foundation is insufficiently established to support their use in court.[1721]

The experience of wrongful convictions is perhaps the most powerful indictment of unreliable forensic evidence. In the United

[1716]DNA Technology (Use and Application) Regulation Bill, 2019 (India), as passed by the Lok Sabha on 8 January 2019.
[1717]Selin Gülgöz and others, 'Developmental Continuity of Genetic Influences on Gender Dysphoria in the General Population' (2020) 117(49) Proceedings of the National Academy of Sciences 31273.
[1718]Brandon L Garrett and Peter J Neufeld, 'Invalid Forensic Science Testimony and Wrongful Convictions' (2009) 95 Virginia Law Review 1.
[1719]President's Council of Advisors on Science and Technology (PCAST), 'Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods' (Executive Office of the President, 2016).
[1720]Itiel E Dror and Greg Hampikian, 'Subjectivity and Bias in Forensic DNA Mixture Interpretation' (2011) 51 Science & Justice 204.
[1721]Supreme Court of India, Selvi v State of Karnataka AIR 2010 SC 1974, holding that compelled narco-analysis, polygraph and brain mapping tests violate Article 20(3) of the Constitution of India.

States, the Innocence Project has documented over 375 exonerations achieved through post-conviction DNA testing, in a substantial proportion of which flawed forensic science contributed to the original miscarriage of justice.[1722]

These cautionary lessons have direct relevance to India. The integrity of the chain of custody, the accreditation of forensic laboratories, the training and independence of forensic analysts, the adversarial testing of DNA evidence through effective cross-examination—all are prerequisites for ensuring that the power of DNA evidence serves justice rather than subverts it. As Thompson and colleagues have emphasised, effective defence review of forensic DNA evidence requires not merely legal competence but scientific literacy.[1723]

VI. TOWARDS A REGULATORY FRAMEWORK: THE DNA TECHNOLOGY REGULATION BILL, 2019

The DNA Technology (Use and Application) Regulation Bill, 2019 represents India's most ambitious legislative attempt to create a comprehensive regulatory framework for forensic DNA analysis. The Bill proposes the establishment of a National DNA Data Bank, regional DNA Data Banks, and a DNA Regulatory Board to oversee the accreditation of laboratories and the management of DNA profiles. The Bill enumerates the categories of persons whose DNA profiles may be collected and stored—including offenders, suspects, undertrials, missing persons and unidentified human remains.

The Law Commission of India, in its 271st Report, had earlier laid the groundwork for such legislation, recommending a statutory framework that balances the law enforcement utility of DNA databases with robust privacy protections and safeguards against misuse.[1724]

Civil liberties scholars and practitioners have raised serious objections to the Bill's scope. The inclusion of suspects and undertrials—persons who have not been convicted of any offence—in a DNA database raises profound presumption of innocence concerns. The absence of robust provisions for the expungement of profiles upon acquittal, the broad discretion afforded to executive authorities in determining database access, and the inadequate specification of data security requirements have all attracted criticism.

A rights-protective DNA regulation law must accomplish several objectives simultaneously: it must empower forensic investigators with reliable analytical tools; it must establish enforceable standards for laboratory accreditation and analyst qualification; it must protect the DNA data of innocent persons from indefinite retention; it must provide meaningful remedies for database errors; and it must ensure that the benefits of forensic DNA science are accessible across socioeconomic divides—including to marginalised defendants seeking post-conviction review. These requirements are not in fundamental tension; they are the complementary conditions of a legitimate forensic science regime.

VII. CONCLUSIONS AND RECOMMENDATIONS

Forensic DNA evidence occupies an ambivalent position in the Indian criminal justice system: celebrated as an instrument of objective truth, yet vulnerable to the same institutional, procedural and human failures that compromise other forms of evidence. This paper has argued that realising the genuine potential of DNA analysis requires far more than scientific sophistication—it demands legal infrastructure adequate to the technology's power and commensurate with the rights at stake.

[1722]Daubert v Merrell Dow Pharmaceuticals, Inc 509 US 579 (1993); in India, see also State of Himachal Pradesh v Jai Lal (1999) 7 SCC 280 on expert testimony standards.

[1723]Nita A Farahany, 'Searching Secrets' (2012) 160 University of Pennsylvania Law Review 1239, examining privacy dimensions of neurological forensic evidence.

[1724]Erin Murphy, 'Inside the Cell: The Dark Side of Forensic DNA' (Nation Books, 2015) 211.

The following recommendations emerge from the preceding analysis. First, Parliament should enact a revised DNA Technology Regulation Bill that incorporates explicit privacy safeguards, mandatory expungement provisions for acquitted persons and suspects, and an independent oversight board with civil society representation. Second, the central and state governments must substantially invest in forensic laboratory infrastructure and in training programmes that produce analysts capable of meeting international accreditation standards. Third, legal education curricula—including at institutions such as Tamil Nadu Dr. Ambedkar Law University—should incorporate forensic science literacy as a component of criminal law and evidence courses, enabling future advocates to engage meaningfully with expert testimony. Fourth, the judiciary should adopt structured standards for the admission of DNA evidence, drawing on the proportionality and reliability framework that the Supreme Court's fundamental rights jurisprudence now provides. Fifth, defence counsel must be resourced to commission independent forensic review, without which the adversarial testing of prosecution DNA evidence remains illusory.

The arc of criminal justice reform in India, as elsewhere, bends toward evidence-based adjudication. DNA science, properly regulated, rigorously scrutinised, and fairly applied, offers a genuine contribution to that arc. The task of the legal community—scholars, practitioners, legislators and judges alike—is to ensure that this contribution is made on terms that uphold, rather than undermine, the foundational commitments of a constitutional democracy.

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