INDIAN JOURNAL OF LEGAL AFFAIRS AND RESEARCH

VOLUME 3 ISSUE 1

Peer-reviewed, open-access, refereed journal

IJLAR

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www.ijlar.com

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Introduction

Welcome to the Indian Journal of Legal Affairs and Research (IJLAR), a distinguished platform dedicated to the dissemination of comprehensive legal scholarship and academic research. Our mission is to foster an environment where legal professionals, academics, and students can collaborate and contribute to the evolving discourse in the field of law. We strive to publish high-quality, peer-reviewed articles that provide insightful analysis, innovative perspectives, and practical solutions to contemporary legal challenges. The IJLAR is committed to advancing legal knowledge and practice by bridging the gap between theory and practice.

Preface

The Indian Journal of Legal Affairs and Research is a testament to our unwavering commitment to excellence in legal scholarship. This volume presents a curated selection of articles that reflect the diverse and dynamic nature of legal studies today. Our contributors, ranging from esteemed legal scholars to emerging academics, bring forward a rich tapestry of insights that address critical legal issues and offer novel contributions to the field. We are grateful to our editorial board, reviewers, and authors for their dedication and hard work, which have made this publication possible. It is our hope that this journal will serve as a valuable resource for researchers, practitioners, and policymakers, and will inspire further inquiry and debate within the legal community.

Description

The Indian Journal of Legal Affairs and Research is an academic journal that publishes peer-reviewed articles on a wide range of legal topics. Each issue is designed to provide a platform for legal scholars, practitioners, and students to share their research findings, theoretical explorations, and practical insights. Our journal covers various branches of law, including but not limited to constitutional law, international law, criminal law, commercial law, human rights, and environmental law. We are dedicated to ensuring that the articles published in our journal adhere to the highest standards of academic rigor and contribute meaningfully to the understanding and development of legal theories and practices.

THE DOUBLE HELIX IN THE DOCK: A CRITICAL APPRAISAL OF FORENSIC DNA EVIDENCE FROM CRIME SCENE TO COURTROOM

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CHAPTER 1

THE GENETIC WITNESS

Considering the annals of criminal Justice, few developments have been as transformative and paradoxically powerful as the applications of Deoxyribonucleic Acid (DNA) analysis. It is nothing except a single strand of genetic material, undetectable to the human eye, which is now capable of convicting the guilty, exonerating the innocent and resolving decades old-cold cases. It is sometimes referred to as the 'infallible witness' or the 'golden standard' of forensic science. Thus, it is an ultimate trace more of a biological autograph left on a weapon, a whisper of skin cells on a collar, or clearly a signature in body of fluids. The study puts this compelling, genetic Witness in the dock not to diminish its deep worth but to provide it to the rigorous examination it requires.

1A. History of DNA Fingerprinting –

Sir Alec Jeffrey's 1984 discovery of DNA Fingerprinting in Lankester, England was successful in sparking a revolution that changed the course of legal epistemology. Prior to this, forensic identification depended on probability-based evidence fingerprint patterns, hair morphology and blood typing that spoke of likelihood. Upon the discovery of DNA Evidence, with the ability to yield match probability of one in several billion, offered near absolute certainty. It had been the focal point of investigations into the higher profiled sexual assaults and murders, as well as the resolution of the past wrongs.

1B. Introduction in India –

India saw the face of DNA Fingerprint in playing an important role in providing evidence, in the

Nirbhaya Case (2012), by confirming the perpetrators, while projects like Innocence Project have used post-conviction DNA testing to exonerate hundreds of wrongfully imprisoned people, exposing the flaws of witness testimony and older forensic methods.

However, DNA evidence's greatest weakness is the sense of invincibility that surrounds it. A DNA sample's journey involves numerous potential weak points, starting from a crime scene where contamination risks are present, continuing through a laboratory process involving intricate biochemistry and subjective interpretation, and ending with its presentation in a courtroom where statistical probabilities can be misinterpreted. The law must strike a careful balance between embracing a powerful scientific tool and keeping vigilant safeguards against its misuse in order to accomplish justice.

CHAPTER II

HISTORICAL EVOLUTION – A RACE FROM BLOOD GROUPS TO GENETIC FINGERPRINTS

The path of forensic identification is a tale of science's unrelenting quest for certainty a mission to turn the biological evidence found at a crime scene from vague hints into conclusive testimony. Justice depended on much cruder but revolutionary biological indicators even before the double helix reached the courtroom.

2A. The Pre DNA Era –

Forensic serology was at the forefront in the early twentieth century. Now, scientists could categorize a stain by kind instead of just recognizing it as blood. Karl Landsteiner's 1901 discovery of the ABO blood type system made it the first forensic "biomarker." A, B, AB, or O might be used to describe a bloodstain discovered at a crime scene. Although this was a significant advancement, its use was severely constrained because it could only rule out suspects rather than identify them. A "match" was statistically worthless for positive identification because nearly 40% of people shared the most prevalent Type O blood. A panel that enhanced discrimination was created by adding additional blood proteins and enzymes, such as HLA typing and electrophoretic analysis of isoenzymes. However, the underlying issue persisted: these systems examined phenotypes, which were shared by sizable portions of the population and were the expressed

products of genes. According to the law, the evidence they offered was only corroborating and circumstantial, never decisive.

2B. The Revolution of Jeffreys – Father of Genetic Fingerprint

In a University of Leicester laboratory in 1984, the paradigm was upended. Geneticist Sir Alec Jeffreys made a discovery while researching hereditary variation in myoglobin genes. He found that some non- coding DNA sections, known as minisatellites or Variable Number Tandem Repeats, or VNTRs, varied greatly among people. He was able to see a pattern of bands on an X-ray image using a molecular probe; this pattern was specific to each person, with the exception of identical twins. This is what he accurately called a "DNA fingerprint."

The effects were immediate and profound in the actual world. In order to establish a familial link in an immigration case Sarbah v. Home Dept. in 1985, Jeffreys' approach was applied for the first time in a criminal case (Pitchfork) in 1986. In 1983 and 1986, two adolescent girls in Leicestershire were raped and killed. Although a suspect had admitted to the second murder, Jeffreys' DNA analysis demonstrated his innocence and established that the same unidentified individual was responsible for both killings. Before a discussion overheard in a pub indicated that a man called Colin Pitchfork had convinced a buddy to donate a sample in his place, a mass screening of more than 5,000 local men's blood samples failed to uncover a match. After being analysed, Pitchfork's DNA matched, and he was found guilty. This case demonstrated the DNA fingerprint's dual ability to identify the guilty with previously unheard- of accuracy and clear the innocent.

2C. The Technological March: From RFLP to PCR- STR – The Pursuit of Efficiency & Sensitivity

Restriction Fragment Length Polymorphism (RFLP), the first-generation Jeffrey’s approach, was revolutionary yet laborious. It takes weeks to get a result and required huge, high quantity DNA samples (the size of a 10p coin stain). Although its practical use was limited, the evidence it produced was compelling in courts speaking in probability of one in millions or billions.

The next significant advancement was made in 1983 when Kary Mullis invented the Polymerase

Chain Reaction (PCR). By using PCR as a biological photocopier, researchers were able to amplify small, damaged DNA samples into amounts big enough for analysis. With the ability to profile from a single hair follicle, a licked stamp, or decades-old skeletal remains, this revolutionized the field of forensics.

The current international standard was developed by combining PCR with a novel class of genetic markers called Short Tandem Repeats (STRs). Stronger and shorter than VNTRs, STRs are widely distributed across the genome. A typical panel of 15–20 core STR loci (plus a marker for sex determination) is now analysed by forensic labs. A digital DNA profile a string of values that can be readily saved, compared, and statistically weighted is produced by combining their lengths at each location. This PCR-STR technique is:

Extremely Discriminatory: The likelihood of two unrelated people matching at 15–20 loci are extremely low, frequently greater than one in a quadrillion.

Quick & Automated: Analysis can be finished in a few hours or days. Robust: Operates on tiny, outdated, or partially deteriorated samples.

Standardized: Enabling the development of robust national DNA databases that facilitate speculative searches and the connection of serial crimes, such as the NDNAD in the UK and the planned regional databases in India.

2D. The Legal Evolution Mirrors the Scientific

Evidence law underwent an analogous change as a result of this technical advancement. Instead of asking "Is this science generally accepted?" (the Frye Standard), courts had to inquire "Is this methodology scientifically valid and reliably applied in this instance?" (the method influenced by Daubert). Judges and jurors have to learn the vocabulary of population genetics, random match probabilities, and likelihood ratios in order to make the transition from a visual "fingerprint" comparison to a probabilistic, statistics-based decision. The "Genetic Witness" was now giving sophisticated mathematical evidence rather than merely showcasing an exhibit.

This historical progression from broad blood groups to highly specific digital STR codes highlights a key idea: the authority of forensic DNA is not innate, but rather created and built upon a century of scientific advancement, each step increasing its power while adding new levels of

complexity for the legal system to understand and control. The consequences of this potent instrument as it moves from the controlled pandemonium of the crime scene to the sombre scrutiny of the courtroom will be examined in the following sections.

CHAPTER III

THE FORENSIC DNA PROCESS: CHAIN OF CUSTODY AND SCIENTIFIC RIGOUR

If the discovery of DNA was revolutionary, its daily use is a painstaking, high-stakes procedure. The voyage of biological evidence is examined in this part, where scientific truth and legal integrity are equally important. The "gold standard" can be turned into tainted evidence by a single mistake or misunderstanding in this procedure, undermining the entire basis of its acceptance in court.

3A. Crime Scene to Lab: The Fragile Cradle of Evidence

The integrity of DNA evidence is determined in the chaotic, uncontrolled setting of a crime scene prior to any sophisticated examination. This stage is controlled by a legally defendable Chain of Custody and the forensic concepts of Locard's Exchange Principle rather than genetics.

Identification of biological material, such as blood, semen, saliva (on cigarette butts, cups), hair roots, skin cells (touch DNA) on weapons, clothes, or ligatures, is the first step in the collection and preservation procedure. Samples from deep tissue (muscle, tooth pulp), femur bones, or fingernail scrapings may be obtained from corpses, particularly in cases of severe decomposition. Sterile instruments are used to collect each sample, which is then air-dried to stop microbial development and kept in breathable paper bags (plastic degrades and condenses).

The evidence's legal lifeblood is the Sacred Chain of Custody. Every individual handling the sample, every transfer, and every storage condition must be carefully recorded from the time of collection. The who, what, when, where, and why must all be included in the record. Any disruption in this chain, such as an unattended sample or an unlogged transfer, exposes the evidence to damaging cross-examination under **Section 136** of the Indian Evidence Act, perhaps making it inadmissible as "tainted." A biological sample becomes a legally recognized exhibit through the chain of custody.

3B. The Laboratory Pipeline:

Amplifying the Signal: Evidence enters a strictly regulated, multi-stage biochemical procedure intended to separate a digital identity from biological noise after it passes the lab barrier.

Extraction and Purification: DNA is released by breaking down cellular material and isolating it from impurities like dyes, dirt, or inhibitors that might interfere with subsequent processes. Everything that comes after depends on how well this “clean-up is done”.

Quantification: Scientists quantify the precise quantity of human DNA using Quantitative PCR (qPCR), which is essential for calibrating the subsequent step to prevent overload or, more importantly, to maximize minute quantities from low-template samples.

PCR Amplification: The Genetic "Xerox": Certain Short Tandem Repeat (STR) loci are targeted and replicated billions of times in a thermal cycler. This makes a small number of DNA molecules manageable. Commercial multiplex kits enable the simultaneous amplification of a sex marker and 15– 20 core loci in a single reaction.

Capillary Electrophoresis: This method involves injecting the amplified DNA into a narrow capillary for separation and readout. The pieces are drawn through by an electric current; smaller pieces travel more quickly. An electropherogram a graph with peaks that represent particular alleles at each genetic locus is created when a laser finds fluorescent tags on each STR.

3C. Profile Generation & Interpretation:

The analyst converts the peaks of the electropherogram into a digital STR profile, which is a distinct string of values (such as 14,17 at locus D3S1358). Probabilistic genotyping software (such as STR mix) employs statistical models to deconvolute mixtures and compute probability ratios for complicated or low-level samples, going beyond simple yes/no matches to weighted findings. To put it simply, the lab pipeline is a machine that turns a biological material into a statistical assertion. Since every stage has the potential to be contaminated or fail, transparent documentation and authorized processes are essential requirements for credibility.

3D. Evidentiary Value: Decoding the "Match":

Here, science satisfies the legal requirement for clarity. A "match" in a forensic report is the start of legal reasoning, not its conclusion.

What a "Match" What It Actually Means: A "match" in forensics refers to a DNA profile from the crime scene sample that is consistent with the suspect's profile (or is a combination that contains the suspect's profile). It does not establish the suspect's presence at the scene on its own. The accompanying statistic provides the power.

The fundamental statistic is Random Match Probability (RMP): It responds to the query: "What is the probability that a randomly selected, unrelated individual from a given population would, by chance, have the same DNA profile as the one found in the evidence?" This likelihood can be astronomically low for a complete 15-locus STR profile, such as 1 in 1 quadrillion (10^15), which is far higher than the global population. DNA's persuasive weight comes from this statistic.

Likelihood Ratio (LR): It contrasts the likelihood of the evidence if the suspect is the contributor (the prosecution's hypothesis) with the likelihood if an unconnected random individual is the contributor (the defence hypothesis). An LR of 1 million indicates that the evidence is a million times more likely to support the prosecution's theory.

3D. The Power of Inclusion and Exclusion –

This is the fundamental quality of DNA.

a) Exclusion: The suspect can be categorically ruled out as the source of the evidence if their profiles do not match. This is a definitive conclusion.
b) Inclusion: If profiles match, there is no conclusive evidence of guilt; rather, it is an inclusion. The RMP or LR communicates the strength of that inclusion. Integrating this potent biological truth into the case's circumstantial mosaic is the legal challenge.

***Legal Crucible*:** It's difficult to present this statistical data. By falsely informing the jury that "there is only a 1 in a billion chance the DNA came from someone other than the defendant," a prosecutor's fallacy transposes conditional probability. Logically, this is incorrect. The right

answer is: "If the DNA came from someone other than the defendant, the chance of seeing this match is 1 in a billion." Indian courts have emphasized in instances such as Rajiv Singh Raju Golu v. State of Bihar that DNA evidence, no matter how powerful, must be backed by an uninterrupted chain of custody and cannot serve as the only foundation for conviction without corroboration. The evidence comes into the courtroom as a very potent piece of a puzzle whose significance must be properly and meticulously explained in the face of adversary examination rather than as an unquestionable oracle.

CHAPTER IV

4. The Legal Scrutiny: Admissibility And Weight In Common Law Systems

The English Jurisprudence - Although the U.S. Daubert standard has not been formally adopted in the UK, its validity and reliability principles have a significant impact on judicial gatekeeping. In addition to cautioning against the Prosecutor's Fallacy and requiring explicit jury instruction on Random Match Probability (RMP), the case of R v. Doheny & Adams [1997] established fundamental rules for presenting statistical DNA evidence. Courts use the dependability test described in R v. Dlugosz for innovative methodologies, determining if the science is trustworthy enough for a jury to take into account. In R v. Weller [2010], the Court of Appeal specifically addressed the dispute surrounding low- template DNA (LTDNA), allowing its admittance but emphasizing the need for expert clarity regarding its limits and increased risk of stochastic effects**.**

The Indian Journey - Section 45 of the Indian Evidence Act, 1872, which permits expert opinions on "science or art," is crucial to admissibility. Although DNA analysis is acknowledged as a science, its validity is questioned due to procedural integrity.

The important distinction made in the seminal case of Selvi & Ors. v. State of Karnataka (2010) was that DNA is physical evidence, not testimonial compulsion protected by Article 20(3), hence requiring its collection does not violate the right to self-incrimination. Nonetheless, the Supreme Court has often emphasized that DNA is not perfect. An uninterrupted chain of custody is crucial, because DNA evidence loses its evidential value without it, according to the ruling in Rajiv Singh Raju Golu v. State of Bihar (2021). On the other hand, in Mohan Singh v. State of Bihar (2011), the Court upheld DNA's conclusive ability to prove identification or paternity in both civil and

criminal cases where protocols are adhered to.

This conflicting position was demonstrated in the Nirbhaya Gang Rape-Murder (2012) trial, when DNA matches from victim swabs and possessions, supported by a strong forensic process, produced unquestionable corroborating evidence that resulted in quick convictions and confirmations of the death penalty. Thus, DNA's authority is acknowledged by Indian jurisprudence, but its court acceptance is subject to stringent procedural compliance.

CHAPTER V

CRITICISM AND CONTEMPORARY CHALLENGES –

Scientific Limitations - The "infallible" genetic witness is susceptible. Contamination, whether in labs or at scenes, continues to be a major risk that might implicate innocent people. Low-template or complicated mixture DNA interpretation requires subjective judgment, which raises the possibility of contextual bias, in which an analyst's familiarity with the case affects how they interpret unclear data. The "CSI Effect," which raises jurors' irrational expectations of deterministic, error-free forensic science and gives DNA evidence excessive weight while ignoring its subtle limits, makes this worse.

Ethical and Privacy Concerns - There are serious concerns about civil liberties raised by the growth of forensic DNA databases. Function creep allows for genetic monitoring by expanding databases that were intended created for dangerous criminals to cover arrestees or lesser offenders. Family trees are turned into investigative leads using familial searching, which identifies suspects through partial matches to relatives and implicates people who never gave permission to be included in a database. In addition to challenging fundamental private rights under theories like informational self-determination, this raises the possibility of genetic discrimination.

Systemic Issues - Theoretical dependability is compromised by operational flaws. Justice is delayed and samples are deteriorated by persistent backlogs in underfunded laboratories, a worldwide problem that is particularly severe in India. Reproducibility and evidential consistency are at risk due to the lack of uniformity among Indian laboratories and their disparate certification and methods. The defence's access is restricted by high expenses, which creates a problem with

equality of weaponry. Miscarriages of justice are further increased when legal professionals are not adequately trained to understand sophisticated statistical information. Although the science is strong, its delivery mechanism is frequently its weakest point.

CHAPTER VI

Conclusion Author's Suggestions

The Genetic Witness is a personal, but transformational, tool for justice. Its ability to effectively identify the guilty and definitively rule out the innocent is unmatched. However, our study shows that its authority comes from a precarious chain of scientific rigor, procedural integrity, and knowledgeable legal examination rather than from innate infallibility. Proactive, systemic protections are necessary to address its weaknesses, which range from contamination and interpretative bias to systemic backlogs and ethical overreach.

The threefold reform strategy is suggested in order to strengthen its dependency and public confidence:

A. Scientific Modifications: Consider ISO 17025 certification a requirement for all forensic laboratories. To counteract contextual bias.
B. Legal Enforcements: Adopting uniform national standards (DNA rules) for gathering, analysing and presenting evidence.
C. Policy and framework: Adopting strong data protection regulations that forbid function creep should be established for DNA databases.

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