



Forensic Science: Unraveling Truth in Criminal Investigations

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ABSTRACT

Forensic Science play an essential role in modern criminal justice, focusing its ability to provide objective evidence through an in-depth analysis of notable Indian and global legal cases. The study underscores India's progressive legislative step, Section 176(3) of the Bharatiya Nagarik Suraksha Sanhita (BNSS) 2023, which mandates forensic investigations for offenses punishable by seven or more years of imprisonment. It is helpful in ancient time through its diverse applications, emphasizing their critical function in determining guilt or innocence, thus anchoring fair judicial processes.. It also identifies barriers, such as limited infrastructure and judicial caution, proposing practical solutions to enhance forensic integration. Through doctrinal research and global comparisons, this paper aims to strengthen trust in justice systems by ensuring forensic evidence is reliable, admissible, and aligned with legal principles.

1. Introduction.

The core mission of any criminal justice system is to uncover truth and deliver equitable outcomes. Human testimony, often marred by bias or inconsistency, can falter in complex cases, necessitating the precision of scientific evidence. Forensic science, blending multiple scientific disciplines, applies rigorous methodologies to legal inquiries, addressing gaps left by traditional methods like witness



accounts or circumstantial clues. By providing verifiable data, it enhances investigative accuracy, from identifying perpetrators to reconstructing crime events.

This research examines the vital role of forensic science in modern criminal investigations, exploring its diverse branches and their contributions to evidence analysis. A central focus is India's transformative BNSS 2023 legislation, particularly Section 176(3), which requires forensic evidence collection for serious crimes, marking a shift toward scientific rigor. The paper analyzes landmark Indian and international cases to illustrate forensic science's role in resolving complex cases, ensuring just outcomes. It addresses systemic barriers, such as inadequate facilities and judicial hesitancy, proposing facial expression offering actionable reforms. Through doctrinal analysis and global comparisons, this study proposes solutions to strengthen forensic capabilities, fostering public confidence in justice.

2. Evolution of Forensic Science.

The journey of forensic science is a testament to humanity's enduring quest for truth, beginning with rudimentary inquiries and progressing to highly sophisticated scientific applications. Ancient civilizations, such as the Chinese, utilized basic observational and analytical techniques, famously documented in the "Washing Away Wrongs" manuscript, which detailed methods for examining corpses and recognizing different types of injuries. Similarly, early forms of fingerprint authentication were observed in ancient India. The 18th and 19th centuries marked a pioneering era, witnessing the emergence of foundational disciplines. Mathieu Orfila, considered the father of modern toxicology, made significant strides in detecting poisons like arsenic. Alphonse Bertillon introduced anthropometry, a system for criminal identification based on physical measurements, while photographic documentation of crime scenes also began. The true revolution in forensic science, however, unfolded in the 20th century. Sir Francis Galton and Sir Edward Henry revolutionized criminal identification through their work on fingerprint classification. Karl Landsteiner's discovery of ABO blood groups provided a crucial tool for linking biological evidence to individuals. Later, Calvin Goddard's meticulous work laid the groundwork for modern firearm identification, and Albert S. Osborn made seminal contributions to questioned document examination. Crucially, Edmond Locard's articulation of the "exchange principle" – that every contact leaves a trace – became a cornerstone of trace evidence analysis. The latter half of the 20th century witnessed perhaps the most significant breakthrough with Alec Jeffreys' development of DNA fingerprinting, revolutionizing individual identification. As we navigate the 21st century, forensic science continues its rapid evolution, embracing digital forensics for cybercrime investigation, advancing



forensic genetics beyond basic DNA profiling, and integrating cutting-edge technologies like artificial intelligence and machine learning to enhance analytical capabilities.

3. Types of Forensic Science.

Forensic science encompasses a diverse array of specialized disciplines, each contributing uniquely to the investigation and resolution of criminal cases. Forensic Pathology and Medicine focus on determining the cause and manner of death through autopsies, wound analysis, and clinical examinations. Complementing this, Forensic Anthropology aids in identifying skeletal remains, estimating age, sex, and ancestry, while Forensic Odontology utilizes dental records and bite mark analysis for identification. Forensic Entomology studies insect activity on deceased bodies to estimate the post-mortem interval and provide clues about body movement. In the realm of chemical analysis, Forensic Toxicology and Chemistry analyze biological samples for drugs, poisons, and alcohol, and identify unknown substances, arson residues, or explosives. Forensic Biology, encompassing serology and DNA analysis, is pivotal for identifying and analyzing biological fluids like blood, semen, and saliva, with DNA profiling being the ultimate tool for individualization. Forensic Ballistics, or firearms examination, involves the analysis of firearms, bullets, cartridges, and gunpowder residues, along with trajectory reconstruction. Questioned Document Examination scrutinizes handwriting, typewriting, and detects alterations or forgeries in documents. Fingerprint Analysis, or Dactyloscopy, remains a fundamental technique, relying on the unique patterns of friction ridges for identification. Trace Evidence Analysis involves the microscopic examination of minute evidence such as hair, fibers, paint, glass, and soil, which can link suspects to crime scenes. The digital age has brought forth Digital Forensics, dedicated to the recovery and analysis of data from electronic devices, crucial for cybercrime investigations. Lastly, Forensic Psychology and Psychiatry contribute by providing behavioral profiles, conducting competency evaluations, and performing psychological autopsies to understand the mind of the deceased. These disciplines require expertise and strict protocols, particularly in India, where BNSS 2023 mandates forensic use in serious crimes.

4. Importance of Forensic Science in Criminal Justice System

The significance of forensic science in contemporary criminal justice cannot be overstated. It provides objective and unbiased evidence, which is instrumental in accurately ascertaining truth, either by corroborating or refuting narratives presented by witnesses or suspects. This scientific input guides



investigations by narrowing down suspect pools, identifying modus operandi, and meticulously reconstructing crime scenes. By offering irrefutable proof, forensic science plays a crucial role in enhancing conviction rates for the guilty and, equally important, in preventing wrongful convictions by exonerating the innocent, thereby ensuring justice for both victims and the accused. Furthermore, the increasing sophistication of forensic techniques acts as a powerful psychological deterrent to potential criminal activity.

A truly transformative development in India's legal landscape is the enactment of the BNSS 2023. Specifically, Section 176(3) introduces a groundbreaking mandate: the collection of forensic evidence at the crime scene by a "forensics expert" for all offenses punishable with imprisonment of seven years or more. This provision marks a significant paradigm shift, aiming to reduce reliance on subjective evidence and infuse greater scientific rigor into criminal investigations. The implications for the Indian criminal justice system are profound. Policing will demand enhanced training for crime scene first responders and improved evidence collection protocols. The forensic infrastructure will necessitate an urgent and substantial upgrade, with existing labs requiring modernization and new facilities needing to be established across the nation. A massive recruitment and rigorous training drive for forensic scientists, technicians, and specialized experts will be essential to meet the increased demand. The judiciary, too, will increasingly rely on sophisticated forensic reports, requiring judges and legal professionals to be well-versed in the admissibility and interpretation of scientific evidence. While this mandate holds the potential for significantly higher conviction rates due to robust scientific evidence and a reduction in cases based solely on circumstantial evidence, its successful implementation will undoubtedly face challenges related to funding, personnel, and logistical hurdles in achieving nationwide compliance within the stipulated timeframe.

Forensic science provides multifaceted assistance throughout the various stages of criminal investigations, often serving as the silent witness that speaks volumes. Its primary contribution lies in systematic crime scene processing and reconstruction, where meticulous documentation, collection, and analysis of physical evidence allow investigators to piece together the sequence of events. Forensic disciplines are instrumental in the positive identification of perpetrators and victims, utilizing techniques like DNA profiling, fingerprint analysis, dental records, and anthropological markers. A core principle, Locard's Exchange Principle, underpins the ability of forensic scientists to link suspects to crime scenes, victims, or weapons through the analysis of transferred trace evidence. Forensic analysis can also decisively establish or disprove alibis, examining call records, digital footprints, or physical evidence that either corroborates or contradicts a suspect's statement. The identification of unknown substances, be it



drugs, explosives, accelerants in arson cases, or poisons, is another critical function. Forensic pathology, through autopsies, determines the precise cause and manner of death, which is fundamental for homicide investigations. Ultimately, forensic scientists provide crucial expert testimony in court, presenting their findings in a clear and comprehensible manner to assist the judiciary in understanding complex scientific evidence, thereby guiding them towards just conclusions.

5. Unraveling Truth in Criminal Cases.

Forensic science is a cornerstone of criminal investigations, delivering precise evidence when traditional methods—eyewitness accounts, confessions, or circumstantial clues—prove inadequate. By applying scientific rigor, forensic disciplines resolve complex cases, ensuring justice through objective analysis. This section examines significant Indian and international cases to demonstrate forensic science's pivotal role in convicting perpetrators, exonerating the innocent, and addressing evidentiary gaps, while exploring obstacles and its broader significance. In India, forensic science often supports traditional evidence but can be decisive in complex cases. In *State of Assam v. Md. Kasum*, DNA evidence from a sexual assault victim's biological samples, analyzed via polymerase chain reaction (PCR), matched the accused's profile with near-certain accuracy, securing a conviction without witnesses. This case underscores DNA profiling's precision in sensitive cases like sexual assault. In *State of Karnataka v. Shivanna*, fingerprint evidence on a murder weapon was critical. Using cyanoacrylate fuming and automated fingerprint systems, investigators-Netflix's fingerprint match linked the accused to the crime, overcoming the lack of eyewitnesses. This highlights the enduring reliability of fingerprint analysis based on unique ridge patterns. Forensic toxicology has also proven vital. In *State of Rajasthan v. Shyam Singh*, analysis of a victim's blood revealed a rare pesticide, directly implicating the accused in a poisoning case with no other evidence. Similarly, in *State of Maharashtra v. Ankur Panwar*, ballistic analysis matched bullet striations to the accused's firearm, solidifying a circumstantial case.

In *State of Uttar Pradesh v. Rajesh Talwar*, blood spatter analysis and DNA evidence reconstructed a murder scene, clarifying conflicting testimonies. Blood spatter patterns, analyzed through fluid dynamics, indicated attacker and victim positions, while DNA corroborated the prosecution's narrative. In *State of Punjab v. Jagtar Singh*, forensic entomology estimated the time of death via insect larvae, supporting the prosecution. The Nirbhaya Case relied on DNA evidence from multiple victims, securing convictions in a high-profile case.

However, procedural errors can undermine forensic evidence. In *Kattavellai @ Devakar v. State of Tamil Nadu*, the Supreme Court rejected DNA evidence due to improper storage and delayed transport, risking



contamination. Similarly, *Vijan Mandal v. State of Chhattisgarh* dismissed DNA evidence due to inadequate sealing and documentation, emphasizing the need for strict protocols. In *State of Kerala v. Anil Kumar*, digital forensics recovered deleted messages, proving fraud, while *State of Delhi v. Santosh Kumar* used ballistic evidence to confirm a firearm match. Globally, forensic science has revolutionized investigations. The Colin Pitchfork Case was the first to use DNA profiling, convicting Pitchfork and exonerating an innocent suspect via mass screening. The Wayne Williams Case used trace evidence—carpet fibers and pet hairs—to link Williams to multiple murders, proving the value of microscopic clues. Digital forensics has transformed modern cases. In the BTK Killer Case (2005, USA), metadata from a Word document revealed Dennis Rader's identity, leading to his conviction for 10 murders. The Dr. Hawley Harvey Crippen Case used forensic pathology (scopolamine detection) and dental forensics to secure a conviction. The Christine and Derek Eley Case leveraged forensic entomology to establish the time of death. The Golden State Killer Case used genetic genealogy to identify Joseph James DeAngelo, convicted of 13 murders. The Jeanne Clery Case (1986, USA) was solved in 2000 with advanced DNA techniques. The 1992 Minneapolis Murder Case (2018) matched DNA from a discarded napkin to Jerry Westrom. The Green River Killer Case convicted Gary Ridgway via DNA evidence. The Lindbergh Baby Kidnapping Case used document analysis and wood grain matching to convict Bruno Hauptmann.

Additional cases highlight forensic diversity. The O.J. Simpson Case (1995, USA) centered on DNA evidence, though controversial, while *R v. Robert Pickton* used forensic anthropology to identify victims' remains. The Maddie McCann Case continues to rely on DNA and trace evidence, demonstrating forensic persistence.

6. Challenges and Limitations.

Despite its immense capabilities, forensic science, both globally and particularly in India, grapples with a myriad of challenges and inherent limitations that hinder its optimal functioning and integration into the criminal justice system. A significant impediment is the prevailing infrastructure deficiencies, characterized by outdated equipment, an insufficient number of well-equipped laboratories, and a dire lack of specialized forensic units across various states and districts. This is compounded by a severe shortage of trained personnel; there is a dearth of qualified forensic scientists, high attrition rates, and often inadequate, outdated training programs that fail to keep pace with rapid scientific advancements. Funding constraints further exacerbate these issues, with limited budgetary allocations for essential research, infrastructure upgrades, and competitive remuneration for personnel. Consequently, many forensic laboratories face overwhelming backlogs of cases, leading to prolonged investigation periods



and significant delays in report generation, which ultimately impacts the constitutional right to a speedy trial.

Moreover, issues surrounding quality control and accreditation remain pertinent. The absence of universal accreditation standards across all forensic labs and varying methodologies can lead to inconsistent results, raising questions about the accuracy and reliability of forensic findings, alongside the ever-present potential for human error or evidence contamination. A distinctive challenge in India, contrasting with many foreign jurisdictions, lies in the sometimes-reserved judicial approach of its apex court towards the admissibility of certain forensic science techniques, particularly those perceived to touch upon fundamental rights. For instance, in the landmark case of *Selvi & Ors v. State of Karnataka*, the Indian Supreme Court held that involuntary administration of narco-analysis, polygraph (lie detector), and brain electrical activation profile (BEAP) tests violated the right against self-incrimination under Article 20(3) and personal liberty under Article 21 of the Constitution. While acknowledging the utility of these techniques as investigative tools, the Court explicitly ruled that any statements made during such compelled tests would not be admissible as evidence. This judgment, while safeguarding constitutional rights, has sometimes been interpreted as raising doubts about the unqualified admission of forensic evidence derived from certain advanced investigative methods, even when voluntarily undergone, contrasting with some foreign legal systems where the reliability and scientific validity, rather than the mode of collection from the accused, are the primary criteria for admissibility. In **Amlesh Kumar Vs. State of Bihar** Apex Court reiterated selvi case, emphasizing that involuntary administration of scientific techniques like narco-analysis, polygraph tests, and brain mapping violates the right against self-incrimination under Article 20(3) and the right to personal liberty under Article 21 of the Indian Constitution. In **kattavellai @ devakar v state of Tamil Nadu**, in this case Supreme Court reviewed the use of DNA evidence in a trial. The prosecution used DNA samples, including vaginal swabs from the victim, to prove the crime and connect the accused to it. However, the Court found serious flaws in how the DNA evidence was handled, leading to its rejection. This case shows the challenges of using scientific evidence in India's criminal justice system and offers insights for improving its reliability. The Court identified several issues in the handling of DNA evidence, which made it unreliable:

The Supreme Court ruled that DNA evidence must be collected, stored, and tested carefully to be trusted in court. In this case, the prosecution failed to follow proper procedures, such as keeping clear records or ensuring safe storage. The Court noted that these problems are common in India, as seen in earlier cases, and can lead to evidence being rejected, even if it could have been useful. The Court stressed that



scientific evidence, like DNA, is powerful but requires strict handling to ensure fairness in trials. Sometime court reject prosecution evidence on small discrepancies and acquittal the accused. **Vijan Mandal vs State Of Chhattisgarh** the court rejected the DNA report. In this case, noting that the prosecution failed to prove the integrity of the DNA evidence due to improper handling and lack of evidence regarding quality control and assurance. It emphasized that the DNA report, being opinion evidence, was not sufficiently corroborated by other substantive evidence, and issues like potential contamination and lack of proper sealing rendered it unreliable. The court held that convictions cannot solely rely on a DNA report without ensuring all precautions in sample collection and preservation were meticulously followed.

Earlier cases like *Pritam Singh v. State of Punjab* had already affirmed the validity of fingerprint and footprint evidence, setting the stage for wider judicial acceptance of forensic disciplines. In court concluded that while **track evidence** is an **unsatisfactory and rudimentary science**, it can be relied upon as a circumstance when coupled with other evidence, but **not as a sole basis for conviction**. In *Shankaria v State of Rajasthan* the Supreme Court ruled that **footprint evidence** is an **undeveloped science** and is **not sufficient for a conviction on its own**. Similarly, *Mohd. Aman v. State of Rajasthan* highlighted the utility of fingerprints while also cautioning that other sciences, like footprint analysis, were not yet fully developed and required careful judicial consideration.

The general admissibility and interpretation of forensic evidence in court also pose challenges; the scientific validity of certain techniques is occasionally scrutinized, and the complex scientific findings often need to be effectively presented and explained to a lay judiciary or jury. Cognitive bias, though often unconscious, can potentially influence forensic examiners' interpretations. Ethical concerns, particularly regarding privacy issues surrounding DNA databases and the responsible use of rapidly evolving technologies, also demand careful consideration. Furthermore, forensic science constantly struggles to keep pace with emerging crime trends, such as sophisticated cybercrimes, new forms of illicit substances, and evolving criminal methodologies, necessitating continuous adaptation and resource allocation. Finally, gaps in legal frameworks and the slow pace of legal reforms often mean that new forensic technologies and their evidentiary value are not adequately addressed, leading to ambiguities in their application and admissibility.

7. Recommendations.



To maximize the efficacy of forensic science in elucidating truth within criminal investigations, a holistic strategy encompassing systemic reforms and targeted investments is essential. Drawing from judicial insights in cases such as *Kattavellai @ Devakar v. State of Tamil Nadu* and *Vijan Mandal vs. State of Chhattisgarh*, which exposed deficiencies in forensic evidence handling, the following measures aim to enhance reliability and credibility in forensic practices.

- 1. Effective Implementation of BharatiyaNagarik Suraksha Sanhita (BNSS) 2023**
Implementing the BNSS 2023 demands a structured, time-bound plan to establish and modernize forensic facilities nationwide. This includes setting clear milestones and accountability frameworks. The Supreme Court in *Kattavellai @ Devakar* mandated that DNA samples be transported to laboratories within 48 hours, with delays documented to prevent contamination risks. Significant budgetary allocations are necessary for advanced forensic tools and secure evidence storage, addressing issues highlighted in *Vijan Mandal*, where the court dismissed DNA evidence due to inadequate chain-of-custody records and improper sealing.
- 2. Enhancing Human Capital in Forensic Science**
A nationwide recruitment initiative for forensic experts, supported by competitive compensation and incentives, is critical to attract skilled professionals. Continuous training in advanced forensic techniques, such as DNA analysis, is vital, as emphasized in *Kattavellai*, which underscored the need for qualified personnel to ensure reliable outcomes. Establishing specialized forensic science institutions and fostering global partnerships for knowledge exchange will cultivate expertise, mitigating errors like those in *Vijan Mandal*, where mishandled DNA samples weakened the prosecution's case.
- 3. Ensuring Rigorous Quality Control and Standardization**
Adopting global standards like ISO/IEC 17025 for all forensic laboratories is crucial to ensure consistency and trustworthiness. The *Kattavellai* ruling stressed quality assurance, rejecting DNA evidence due to lapses in storage and chain-of-custody protocols. Regular third-party proficiency testing for forensic disciplines, including DNA profiling, will prevent issues like those in *Vijan Mandal*, where the court deemed DNA reports unreliable absent corroborative evidence. Standardized procedures for evidence collection and analysis, as mandated in *Kattavellai*, are imperative.
- 4. Improving Judicial and Legal Competence in Forensics**
Comprehensive training for judges, prosecutors, and defense attorneys on forensic science principles and limitations is essential. In *Pattu Rajan v. State of Tamil Nadu*, the Supreme Court noted that DNA evidence, as opinion



evidence under Section 45 of the Indian Evidence Act, 1872, requires careful judicial evaluation. The *Kattavellai* judgment further advocated for clear guidelines on forensic evidence admissibility to prevent reliance on flawed reports, as seen in *Vijan Mandal*, where contamination risks undermined DNA evidence credibility.

5. **Promoting Indigenous Research and Innovation** Encouraging research tailored to India's unique forensic challenges is vital. Collaborative public-private partnerships can drive technological advancements, as recommended in *Kattavellai*, to meet evolving evidentiary needs. Research into techniques like mini-STRs for degraded DNA, noted in *Vijan Mandal*, can enhance accuracy. Dedicated research institutes will support context-specific forensic solutions, strengthening the justice system.
6. **Compliance with Supreme Court Directives** Law enforcement must adhere to *Kattavellai @ Devakar v. State of Tamil Nadu* guidelines, including:
 - A. **Documentation:** Comprehensive records of sample collection, detailing the accused or victim's identity, injury marks, and examination timing.
 - B. **Chain of Custody:** Samples must reach forensic laboratories within 48 hours, with delays justified in case diaries.
 - C. **Preservation:** Evidence must be stored appropriately to avoid contamination, a critical issue in *Kattavellai* and *Vijan Mandal*. These measures aim to standardize forensic processes and prevent procedural lapses.
7. **Strengthening Inter-Agency Coordination and Digital Forensics:** Robust coordination among law enforcement, forensic laboratories, and the judiciary is essential for efficient evidence processing. The *Kattavellai* judgment emphasized inter-agency collaboration to maintain evidence integrity. Establishing specialized cyber forensic units in every state, equipped with cutting-edge technology, is crucial to address digital evidence challenges. Legal frameworks under the BNSS 2023 must evolve to regulate digital evidence collection and admissibility, aligning with constitutional protections under Article 21, as highlighted in *Kattavellai*.

By implementing these strategies, informed by precedents like *Kattavellai @ Devakar v. State of Tamil Nadu* and *Vijan Mandal vs. State of Chhattisgarh*, forensic science can reliably serve



justice, ensuring evidence is credible, admissible, and aligned with principles of fairness and due process.

8. Conclusion

Forensic science is vital for delivering objective evidence, resolving complex cases, and ensuring justice. India's BNSS 2023 mandate highlights its importance, but barriers like infrastructure and procedural lapses must be addressed. Landmark cases demonstrate forensic science's transformative potential. Robust reforms will enhance its reliability, fostering equitable justice. Indian courts balance forensic admissibility with constitutional protections. In *Selvi & Ors v. State of Karnataka*, involuntary narco-analysis and polygraph tests were deemed unconstitutional, unlike the USA's Daubert standard, which prioritizes scientific reliability. Indian cases like *Kattavellai* highlight procedural rigor, while international cases emphasize robust evidence handling.

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