
FORENSIC AND OTHER MODERN TOOLS AND TECHNIQUES IN CRIMINAL INVESTIGATION

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ABSTRACT

The swift progress of science and technology has profoundly reshaped the functioning of criminal justice, especially in investigation, evidence gathering, and adjudication. Forensic disciplines and contemporary investigative methods have improved the precision, trustworthiness, and speed of crime detection by allowing law enforcement to depend on scientific techniques rather than primarily on oral testimony or confessions. Methods like DNA analysis, cyber forensics, digital monitoring, forensic ballistics, and forensic psychology are now vital for tackling modern offences such as cybercrime, terrorism, organized crime, and transnational violations. This article provides a critical appraisal of forensic and other modern investigative methods used in criminal probes, their legal admissibility, practical uses, and attendant challenges, with particular reference to the Indian criminal justice framework. The study also underscores the imperative to reconcile technological progress with constitutional protections and human rights.

Keywords: Forensic Science; Criminal Investigation; Modern Investigative Techniques; Digital Forensics; DNA Profiling; Cyber Forensics; Indian Criminal Justice System.

INTRODUCTION

Forensic science denotes the application of scientific principles and methods to legal questions, notably in crime investigation and prosecution. Historically, criminal enquiries depended heavily on eyewitness accounts, confessions, and circumstantial indicators. Such approaches, however, were prone to subjectivity, coercion, and significant error. The rise of forensic science brought a fundamental change by introducing objective, science-based, and technologically informed methods into investigative practice.¹ Contemporary investigative techniques cover a broad array of scientific and technical processes, including biological assays, examination of digital data, chemical analyses, and behavioural profiling. These methods aid investigators in reconstructing scenes, identifying suspects, linking accused persons to offences, and corroborating material presented in court.² As globalization, technological advancement, and digital interconnectivity have made crimes more sophisticated, conventional methods alone are inadequate for offences like cyber fraud, online sexual violence, terrorism financing, and organized criminal operations. Therefore, forensic and modern tools have become indispensable to effective policing and criminal justice administration. In India, the role of forensic science has been increasingly acknowledged through institutional developments such as the setting up of forensic laboratories, the enactment of the Bharatiya Sakshya Adhiniyam, 2023, and judicial reliance on scientific proof in criminal proceedings. Still, problems like insufficient infrastructure, shortage of trained staff, delays in forensic outputs, and risks of technological misuse remain.³

2. Types of Forensic Science Used in Criminal Investigation

Forensic science is interdisciplinary, consisting of numerous specialized branches, each performing unique functions in criminal probes. These disciplines apply scientific expertise to examine physical, biological, and digital traces, thereby assisting police and courts in establishing facts. The main forensic branches commonly applied in investigations are outlined below.

2.1 Forensic Fingerprint Analysis

Fingerprint examination is among the oldest and most widely trusted identification methods in

¹ Ratanlal & Dhirajlal, *The Law of Evidence* 439–445 (26th ed. 2022).

² Ratanlal & Dhirajlal, *The Law of Evidence* 439–445 (26th ed. 2022).

³ Paul C. Giannelli, *Scientific Evidence in Criminal Prosecutions*, 137 *Mil. L. Rev.* 167 (1992).

forensics. It rests on the principle that fingerprints are unique to each person and remain stable over a lifetime. Latent prints recovered at scenes are compared with known prints from suspects to confirm identity. Fingerprint evidence is broadly used in burglary, theft, homicide, and identity-fraud cases, and is highly credible when correctly retrieved and examined.

2.2 Forensic Ballistics

Forensic ballistics involves the study of firearms, ammunition, projectiles, cartridge cases, and gunshot residues. By microscopically comparing striations and tool marks, ballistic specialists can ascertain whether a particular weapon was used in an offence. This field is crucial in murders, armed robberies, and encounter cases, helping to connect a firearm to the criminal act.

2.3 Forensic Pathology

Forensic pathology concentrates on determining cause, manner, and time of death through post-mortem examinations. It is essential in suspicious deaths, custodial fatalities, homicides, and mass-casualty events. By assessing injuries, organ damage, and disease states, forensic pathologists help courts distinguish between natural, accidental, suicidal, and homicidal deaths.

2.4 Forensic Serology

Forensic serology concerns the detection and analysis of bodily fluids—blood, semen, saliva, sweat—found at crime scenes. Serological tests identify blood groups and the presence of biological material that may subsequently undergo DNA testing. This area is particularly important in sexual offences and violent crimes.⁴

2.5 Forensic Toxicology

Forensic toxicology addresses the detection and quantification of drugs, alcohol, poisons, and chemicals in biological specimens. It is vital in poisoning cases, overdoses, intoxication-related offences, and deaths linked to substance use. Toxicology reports frequently underpin determinations of criminal responsibility in such matters.

⁴ Selvi v. State of Karnataka, (2010) 7 S.C.C. 263 (India).

3. Modern Forensic Tools and Scientific Techniques

Modern forensic instruments reflect the fusion of advanced science with investigative work, empowering law enforcement to confront complex, technology-driven crimes. These approaches bolster evidentiary reliability by reducing subjective judgment and increasing objectivity in investigations.⁵

3.1 DNA Profiling

DNA profiling is a sophisticated technique based on analysing deoxyribonucleic acid, which encodes individual genetic identity. Minute biological traces—skin cells, hair roots, saliva—left at scenes can be examined to produce a DNA profile. This method is invaluable for identifying perpetrators in serious offences, particularly sexual assaults and homicides, where biological material is often available. Beyond detection, DNA profiling has exonerated wrongly convicted persons and assists in identifying missing individuals, disaster victims, and in parentage disputes. The probative strength of DNA evidence depends on rigorous collection protocols, proper preservation, and an intact chain of custody to avoid contamination or misuse.

3.2 Digital Forensics

Digital forensics entails systematically examining electronic devices to recover data usable in criminal prosecutions. Today, almost every offence leaves some digital trace—phone activity, internet use, electronic transactions, or surveillance footage. Digital forensic practitioners use dedicated software and hardware to retrieve deleted files, decrypt protected data, and examine metadata like timestamps and geolocation. Digital forensics is not confined to cyber offences; it supports conventional investigations by providing corroborative material. Call-detail records, GPS data, and social media interactions commonly help establish motive, opportunity, and presence at a scene. Given the ephemeral nature of digital information, proper forensic imaging and preservation are critical to safeguarding evidentiary integrity.

3.3 Cyber Forensics

Cyber forensics targets crimes perpetrated in cyberspace, where offenders exploit anonymity and jurisdictional gaps. This discipline analyses network traffic, server logs, IP addresses, and

⁵ State of H.P. v. Jai Lal, (1999) 7 S.C.C. 280 (India).

online communications to trace cybercriminal actions. Cyber forensics uncovers complex digital networks involved in online fraud, cyberterrorism, data breaches, and child sexual exploitation material. Because cyber offences often cross borders, cyber forensics facilitates international cooperation by producing technical evidence shareable with foreign agencies. Nonetheless, factors like encryption, dark-web use, and rapid technological change complicate these inquiries.⁶

3.4 Advanced Forensic Toxicology

Contemporary forensic toxicology uses highly sensitive analytical instrumentation to detect and measure toxic agents in biological samples. These methods identify drugs, alcohol, pesticides, heavy metals, and other poisons, even in trace quantities. Advanced toxicology is especially pertinent in slow poisonings, drug-facilitated sexual assaults, and deaths from substance misuse. The scientific exactitude of modern toxicology aids courts in more confidently determining causes of death or impairment. Toxicological results often serve as pivotal corroborative evidence alongside medical and circumstantial material.⁷

3.5 Voice, Audio, and Speech Forensics

Voice and speech forensics involve scientifically examining audio recordings to identify speakers and verify recordings. Contemporary tools enable analysis of pitch, frequency, tone, and idiosyncratic speech patterns. These methods are frequently applied in ransom, extortion, terrorism, and organized-crime cases where voice communication is central. Besides speaker identification, audio forensics can enhance poor-quality recordings, detect edits, and authenticate digital audio. Courts typically require such evidence to be backed by expert testimony and corroboration, given the risk of manipulation.

4. Other Modern Investigative Tools and Techniques (Technology-Driven Methods Beyond Forensic Science)

Beyond laboratory-based forensics, contemporary investigations increasingly draw on technology-driven instruments that assist police in surveillance, intelligence, prevention, and suspect identification. Though not strictly forensic, these tools play essential supportive roles

⁶ Anvar P.V. v. P.K. Basheer, (2014) 10 S.C.C. 473 (India).

⁷ Mukesh v. State (NCT of Delhi), (2017) 6 S.C.C. 1 (India).

in bolstering inquiries and ensuring effective law enforcement.⁸

4.1 Polygraph Test, Narco-Analysis, and Brain Mapping

These methods are collectively termed scientific interrogation techniques. A polygraph registers physiological responses—blood pressure, heart rate, respiration—to gauge truthfulness during questioning. Narco-analysis involves administering drugs to induce a semi-conscious state in which a subject may disclose information. Brain mapping, or Brain Electrical Activation Profile (BEAP), examines neural responses to stimuli to detect familiarity with certain facts. While they may generate investigative leads, their evidentiary worth is limited by constitutional protections against self-incrimination and the need for voluntary consent. Courts generally allow their use for investigative purposes only, not as definitive proof of guilt.

4.2 CCTV Surveillance and Video Forensics

Closed-circuit television (CCTV) has become indispensable in modern policing. Cameras in public and private spaces help monitor offences, identify suspects, and reconstruct events. Video forensic techniques enhance CCTV utility by clarifying images, stabilizing footage, and validating authenticity. Video evidence often decisively establishes event sequences, supports witness testimony, and refutes false claims. Nevertheless, privacy, data protection, and potential misuse concerns require legal checks and oversight.⁹

4.3 Geographic Information Systems (GIS) and Crime Mapping

Geographic Information Systems (GIS) analyse spatial data related to crime patterns. By mapping hotspots and trends, police can deploy resources more effectively and adopt preventive measures. GIS-based mapping underpins predictive policing by identifying areas at higher risk based on historical data. This tool is particularly helpful in urban policing, traffic control, and disaster response, enabling authorities to make informed, data-driven decisions.

4.4 Artificial Intelligence and Big Data Analytics

Artificial Intelligence (AI) and big data analytics have become potent aids in investigations. AI systems are used for facial recognition, pattern detection, predictive policing, and automated

⁸ Arjun Panditrao Khotkar v. Kailash Kushanrao Gorantyal, (2020) 7 S.C.C. 1 (India).

⁹ Pattipati Venkaiah v. State of Andhra Pradesh, A.I.R. 1985 S.C. 1715 (India).

processing of large datasets. Big data techniques allow investigators to sift through voluminous information from digital records, financial transactions, social media, and surveillance feeds. While these technologies boost efficiency and analytic capability, they raise issues of algorithmic bias, data quality, and privacy infringement. Their deployment must therefore be governed by transparency, accountability, and legal constraints.¹⁰

5. Evidentiary Value and Legal Admissibility of Forensic and Modern Tools

The strength of forensic and modern investigative tools as evidence lies in their capacity to produce objective, scientific, and corroborative material for criminal trials. Unlike oral testimony, which can be affected by memory lapses, coercion, or prejudice, forensic evidence is grounded in scientific methodology and specialist expertise. Consequently, courts increasingly depend on such material to promote fair adjudication and reduce wrongful convictions. Forensic findings are typically presented through expert witnesses, who explain the scientific rationale, methods used, and results obtained. The persuasiveness of this evidence depends on the expert's qualifications, the reliability of the technique, and adherence to standard protocols in collection and analysis. Under Indian evidence law, scientific and forensic material is admissible. The Bharatiya Sakshya Adhiniyam, 2023, broadened the scope of admissible electronic and scientific proof by explicitly acknowledging digital records, electronic data, and outputs from modern technologies. This legislative change reflects judicial acceptance of technological evidence in criminal proceedings. Admissibility, however, is not automatic. Courts scrutinize whether evidence was gathered lawfully and without infringing fundamental rights. An unbroken chain of custody must be shown to prove the item was not tampered with. Procedural errors, contamination, or unexplained delays in forensic testing may erode probative value.¹¹

Electronic and digital evidence, in particular, must meet additional standards of authenticity and integrity; courts require assurance that records were not altered and that proper forensic methods were used in extraction and analysis. Lacking such safeguards, the evidentiary worth of digital forensic material may be greatly reduced. While forensic tools significantly bolster the prosecution's case, courts often treat them as corroborative rather than determinative.

¹⁰ Malimath Comm. on Reforms of Criminal Justice System, Ministry of Home Affairs, Gov't of India (2003).

¹¹ Pattipati Venkaiah v. State of Andhra Pradesh, A.I.R. 1985 S.C. 1715 (India).

Scientific evidence is usually evaluated alongside circumstantial facts, witness accounts, and other material to form a comprehensive finding on guilt or innocence.

6. Challenges and Limitations in the Use of Forensic and Modern Tools

Despite growing dependence on forensic science and contemporary investigative methods, multiple challenges and limits hinder their effective deployment within the criminal justice system. These obstacles span infrastructural, procedural, legal, and ethical areas and affect the reliability and timely use of forensic evidence. A chief difficulty is inadequate forensic infrastructure, especially in developing regions.¹² Many forensic laboratories are understaffed, poorly equipped, and burdened with backlogs. Such constraints cause significant delays in reports, impinging on the right to a speedy trial and weakening prosecutions as corroborative evidence fades. Another major issue is the scarcity of trained specialists. Forensic work demands high technical skill, continuous training, and compliance with evolving scientific norms. Improper collection, preservation, or handling of evidence by insufficiently trained personnel can lead to contamination or loss of value, rendering otherwise critical scientific evidence inadmissible or unreliable. Procedural lapses also present serious problems. Failure to maintain an intact chain of custody undermines the credibility of forensic material. Courts are wary of scientific evidence when there is uncertainty about who handled it, how it was stored, and whether it was protected from interference. Ethical and constitutional issues further constrain the use of certain modern tools. Techniques like pervasive surveillance, facial recognition, and mass data mining raise grave privacy concerns. Unchecked deployment of technology can violate the right to privacy and personal liberty.¹³ Likewise, scientific interrogation methods raise questions about self-incrimination and voluntariness. Moreover, excessive reliance on forensic evidence can foster investigative complacency. Scientific methods are meant to support, not supplant, diligent police work. Errors in forensic analysis, if uncritically accepted, may produce miscarriages of justice. Hence, courts advocate careful, critical appraisal of scientific evidence rather than unquestioning acceptance.

7. Role of Forensic Science in Crime Detection and Prevention

Forensic science is pivotal not only in investigating and prosecuting offences but also in detecting and preventing crime. By introducing objectivity, scientific precision, and

¹² David L. Faigman et al., *Modern Scientific Evidence: The Law and Science of Expert Testimony* (2020).

¹³ Bharatiya Sakshya Adhinyam, No. 47 of 2023, India Code (2023).

technological accuracy into justice processes, forensic tools greatly enhance law enforcement's capacity to identify offenders, reconstruct events, and deter criminal conduct. In detection, forensic science helps link offenders, victims, and scenes. Physical and biological traces—fingerprints, DNA, ballistic marks, and digital residues—provide concrete leads that aid in suspect identification with high certainty. Unlike traditional methods that often lean on confessions or eyewitnesses, forensic evidence reduces the chance of wrongful implication and investigative bias. Forensic databases further strengthen detection mechanisms. Repositories of fingerprints, DNA profiles, ballistic data, and criminal records enable rapid cross-referencing and pattern matching. Repeat offenders can be identified more quickly, and cold cases reopened when new forensic matches surface. This systematic use of forensic data improves detection rates and investigative efficiency. From a preventive standpoint, the visible use of forensic science deters criminal activity. Knowledge that offences can be scientifically traced and proven discourages potential offenders. Surveillance systems, biometric identification, and digital monitoring reduce anonymity and therefore lower the likelihood of criminal behaviour. Forensic science also supports preventive policing strategies. Crime mapping, digital surveillance, and analytics help authorities identify hotspots and patterns. By examining past data, resources can be allocated strategically, patrols targeted, and early interventions implemented. Such proactive application shifts focus from reactive investigation to crime prevention.¹⁴ Additionally, forensic tools prevent miscarriages of justice by enabling accurate identification and reliable evidence, thereby protecting innocent persons from wrongful prosecution. This function is essential for maintaining public trust in the justice system and upholding the rule of law. In India, institutional emphasis on forensic science reflects its role in crime control and prevention. Yet to realize its full preventive benefit, forensic practice must be backed by proper infrastructure, skilled personnel, standardised procedures, and legal safeguards that balance efficiency with constitutional rights.¹⁵

8. Role of Forensic Experts and Expert Evidence in Criminal Trials

Forensic experts play a central role in the modern justice system, bridging scientific analysis and judicial decision-making. Their contribution goes beyond laboratory tests; they help courts understand complex scientific material and assess the probative value of technical evidence during trials. Expert evidence is necessary when case matters involve specialised knowledge

¹⁴ S. Gopal Reddy v. State of Andhra Pradesh, (1996) 4 S.C.C. 596 (India).

¹⁵ Code of Criminal Procedure, No. 2 of 1974, §§ 45, 293 (India).

beyond the ordinary grasp of judges and lawyers. Forensic specialists offer opinions on DNA results, ballistic comparisons, causes of death, toxicology, digital analyses, and voice identification. Their testimony assists courts in correctly interpreting scientific findings and applying them to the facts. The weight accorded to expert testimony hinges on several factors. Courts evaluate the expert's credentials, training, experience, and impartiality. Experts are expected to present objective findings, explain methodologies, and disclose the limitations of their techniques. Signs of bias, incompetence, or deviation from accepted procedures can substantially diminish an expert's evidentiary value. Forensic experts must also uphold scientific integrity throughout investigations. Proper documentation, adherence to standard operating procedures, and maintenance of chain of custody are core responsibilities. Expert reports should be clear, precise, and scientifically robust, since vague or inconsistent opinions may sow doubt. Judicial treatment of expert evidence treats it as advisory rather than determinative.¹⁶

Courts do not substitute expert views for judicial reasoning; they weigh such evidence alongside other materials—circumstantial facts and witness testimony. When expert opinion aligns with other evidence, it is highly persuasive; where it stands alone or conflicts with other material, courts proceed cautiously. Recently, courts have stressed the need for independence and accountability among forensic experts. Growing reliance on scientific evidence demands high ethical standards to prevent manipulation, fabrication, or misuse. Judicial oversight seeks to ensure that expert testimony aids truth-finding without compromising trial fairness. In India, the role of forensic experts has expanded with statutory recognition of scientific and electronic evidence. Nevertheless, delays in reporting, limited expert availability, and institutional constraints continue to hamper effective use. Addressing these issues is vital to enhance the reliability and credibility of forensic testimony.

9. Forensic Science and Protection of Human Rights

The integration of forensic science into investigations significantly affects human-rights protection within the justice system. While forensic tools improve investigative accuracy, their application must be balanced against fundamental rights such as personal liberty, privacy, dignity, and the right to a fair trial. The relationship between forensic methods and human rights is therefore complementary but also cautious. Forensics contributes to rights protection

¹⁶ National Human Rights Commission, Guidelines on Custodial Death/Rape (2010).

by reducing reliance on coercive practices. Scientific proof diminishes dependence on custodial interrogation, confessions, and subjective judgments historically linked to custodial abuse and rights violations. By supplying objective, verifiable material, forensic techniques help prevent torture, forced admissions, and arbitrary detentions.

A key human-rights benefit of forensics is the prevention of wrongful convictions. DNA and similar methods have been instrumental in exonerating innocent persons, aligning with the rights to life and personal liberty and the presumption of innocence. Accurate scientific identification ensures culpability is assigned to the true perpetrator, bolstering substantive justice. Simultaneously, modern forensic and technological tools pose serious privacy concerns. Surveillance tech, biometric collection, facial recognition, and digital forensics involve extensive data capture, often without explicit consent. Unregulated or excessive use can enable mass surveillance and profiling, undermining individual autonomy and informational privacy. Scientific interrogation methods also raise constitutional issues.¹⁷

Techniques that intrude on mental or bodily integrity threaten dignity, bodily autonomy, and protection against self-incrimination. Using such methods without informed consent contravenes fundamental rights and weakens the fairness of criminal procedures. Forensic practice must respect the right to a fair trial. The accused must be able to contest forensic evidence, cross-examine experts, and challenge the validity of scientific methods deployed against them. Transparency in procedures, access to defence expert assistance, and prompt disclosure of forensic reports are necessary for procedural fairness. In India, courts have consistently held that technological progress cannot displace constitutional safeguards. Use of forensic and modern tools must be governed by legality, necessity, proportionality, and procedural fairness. Robust laws, judicial oversight, and ethical norms are required to ensure forensic science serves justice rather than infringes rights.

10. Use of Forensic and Modern Tools in Special Crimes

The application of forensic science and modern investigative methods is especially important in probing special and complex crimes. These offences often involve sophisticated tactics, organised networks, transnational links, and technological elements, rendering traditional methods inadequate. Forensic and modern tools help uncover hidden evidence, map criminal

¹⁷ National Human Rights Commission, Guidelines on Custodial Death/Rape (2010).

networks, and establish culpability with scientific certainty. In sexual offences, forensic science is decisive in proving the occurrence and identifying the perpetrator. DNA profiling of semen, blood, saliva, and hair links accused persons to victims. Forensic medical examinations document injuries, time of assault, and support victim testimony.

Timely and sensitive forensic use strengthens prosecutions while protecting victim dignity and rights. In terrorism and organised crime, forensic and technological methods are indispensable. Analysis of explosive residues, ballistics, digital communications, and financial forensics helps identify terror cells, trace funding, and reconstruct attack plans. Surveillance, call-detail analysis, and cyber forensics aid in exposing sleeper cells and preventing attacks. Given national-security stakes, these tools are vital for securing convictions while observing due process. Cybercrimes are among the fastest-growing special categories. Cyber forensics enables tracing digital footprints, recovering deleted data, analysing malware, and identifying actors operating across borders. Offences like online fraud, identity theft, cyberstalking, and illegal digital content rely almost entirely on digital evidence; without forensic tools, prosecution would be nearly impossible. In narcotics cases, forensic science identifies and quantifies prohibited substances. Chemical analysis establishes drug identity, purity, and compliance with statutory thresholds.¹⁸

Forensic toxicology aids in matters of drug abuse, fatalities from overdose, and trafficking investigations. For economic offences and financial crimes, forensic accounting and digital forensics trace money laundering, fraudulent transactions, and shell entities. Examination of electronic financial records, payment trails, and encrypted communications helps prove mens rea and conspiratorial links. Overall, using forensic and modern tools in special crimes improves investigative precision, reduces dependence on confessions, and reinforces the rule of law. However, given the gravity of such offences, their deployment must be accompanied by stringent procedural safeguards to prevent abuse and ensure constitutional compliance.

11. Comparative Perspective: Use of Forensic Tools in Other Jurisdictions

A comparative look at forensic science and modern investigative methods across jurisdictions shows varying levels of technological adoption, legal regulation, and judicial acceptance. International experience offers lessons and best practices that can strengthen domestic systems

¹⁸ Federal Rules of Evidence r. 702 (U.S.).

while protecting individual rights. In the United States, forensic science is central to investigations and trials. DNA profiling is institutionalised through national databases, facilitating quick suspect identification and exoneration of the wrongly convicted. Courts apply strict thresholds when admitting scientific evidence, focusing on methodological soundness and expert competence. Digital forensics, cyber investigations, and forensic accounting are highly advanced, supported by specialised agencies and infrastructure. The United Kingdom combines forensic innovation with robust regulatory oversight. Forensic evidence is subject to rigorous quality assurance and accreditation.¹⁹

Independent service providers operate under strict rules, promoting transparency and scientific integrity. Surveillance and biometric tools are regulated by comprehensive data-protection and human-rights laws, reflecting strong emphasis on privacy and proportionality. European jurisdictions generally align forensic practices with human-rights and data-protection norms. Use of biometric data, surveillance, and forensic databases is tightly controlled to avoid misuse. Courts stress procedural fairness, transparency, and the accused's right to challenge scientific evidence. Forensic integration is accompanied by safeguards to protect individual dignity and autonomy. Many developing jurisdictions, including India, face implementation challenges despite judicial recognition of forensic value. Shortages in infrastructure, trained personnel, and delays in analysis impede effective use of scientific tools. Nevertheless, recent legal reforms and institutional initiatives indicate a gradual move toward greater reliance on forensic and digital evidence. Comparative experience shows that forensic science enhances detection and prosecution only where institutional capacity, legal regulation, and judicial oversight are strong. Jurisdictions that integrate forensic tools within a rights-respecting framework provide useful models for reform.²⁰

12. Recent Developments and Emerging Technologies in Forensic Science

Forensic science continually evolves alongside technological change and shifting criminal modalities. Recent innovations and emerging technologies have broadened investigative capabilities, enabling authorities to tackle complex, tech-driven offences with greater speed and accuracy. A major development is the growing use of artificial intelligence (AI) in forensic tasks. AI systems aid facial recognition, fingerprint matching, handwriting analysis, and pattern

¹⁹ *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993).

²⁰ Forensic Science Regulator Act, 2021, c. 11 (U.K.).

detection, rapidly processing large datasets and revealing correlations not obvious to human analysts. AI-assisted forensics speeds analysis and improves accuracy in cases involving voluminous biometric or digital data, though algorithmic bias, transparency, and accountability concerns require regulation. Advances in digital and multimedia forensics are also critical. With widespread smartphone, social-media, and cloud use, vast evidentiary material exists digitally. New techniques permit analysis of encrypted content, recovery from damaged devices, authentication of images and videos, and detection of deepfakes. These tools are essential against cybercrime, misinformation, and digital manipulation. Forensic genetics has expanded beyond conventional DNA profiling.²¹

Methods like forensic genealogy let investigators identify suspects by tracing genetic connections across public or private DNA databases—a technique effective in solving cold cases but raising ethical and privacy questions about consent and data use. Blockchain technology is being explored to secure the integrity of digital evidence. Immutable blockchain records of evidence handling and transfers can reinforce chains of custody and reduce tampering risks, potentially enhancing the credibility of electronic evidence. Additionally, automation and laboratory modernisation have improved throughput and reduced human error. Automated sample processing, digital case management, and standardised protocols promote consistency and dependability in reporting. In India, emerging technologies are progressively integrated through institutional reforms, modern laboratories, and digital evidence frameworks. Effective use of these innovations, however, requires legal clarity, ethical guidelines, skilled personnel, and ongoing oversight to ensure that progress does not erode fundamental rights.

13. Need for Legal and Institutional Reforms

To harness forensic science and contemporary investigative tools effectively, a robust legal and institutional framework is essential to guarantee scientific reliability, procedural fairness, and protection of fundamental rights. While technology has enhanced investigative capacity, legal and institutional arrangements often lag, calling for comprehensive reform. A primary reform area is establishing uniform forensic standards and protocols. Standardised procedures for collection, preservation, analysis, and reporting are crucial for consistency and trustworthiness across jurisdictions. Absence of uniformity produces variability that may undermine scientific

²¹ United Nations Office on Drugs and Crime, Handbook on Forensic Science and Criminal Justice Reform (2014).

evidence in court. Institutional reform is also vital. Strengthening forensic infrastructure by increasing laboratory capacity, upgrading equipment, and reducing backlogs is urgent. Adequate funding and administrative autonomy for forensic bodies will boost efficiency and prevent trial delays. Capacity building and professional development are critical. Forensic specialists, investigators, prosecutors, and judges must receive ongoing training to keep abreast of scientific advances. Sensitisation programs on forensic and digital evidence will improve stakeholders' ability to evaluate and use scientific material effectively. Legal reform must address privacy and data-protection issues stemming from modern tools. Clear statutory rules governing biometric collection, surveillance technologies, and digital forensics are necessary to prevent misuse and ensure proportionality. Judicial oversight should regulate intrusive technologies. Moreover, defence access to forensic resources needs enhancement. Fair-trial principles require that accused persons have reasonable opportunities to challenge forensic evidence, including access to independent experts when needed. Bolstering adversarial equality in forensic matters promotes transparency and justice. In India, recent statutory recognition of electronic and scientific evidence is a positive development. Nonetheless, sustained reforms are required so forensic science becomes a means to justice rather than a source of procedural unfairness. A holistic approach that combines legal clarity, institutional capacity, ethical safeguards, and technological innovation is crucial for the future of criminal investigation.²²

CONCLUSION

Forensic science and modern investigative methods have fundamentally altered the criminal justice landscape by introducing scientific objectivity, technological precision, and greater evidentiary reliability into investigations and trials. Moving from confession-centric practices to evidence-led approaches has improved detection accuracy, reinforced prosecutions, and reduced wrongful convictions. Techniques like DNA profiling, digital and cyber forensics, toxicology, and advanced surveillance are now essential for addressing complex, transnational, and technology-enabled crimes. Simultaneously, heightened reliance on forensic and technological tools presents serious legal, ethical, and constitutional challenges. Concerns about privacy, data protection, human dignity, and fair-trial rights underline the need for measured and regulated use. Scientific progress must not override fundamental rights or procedural fairness. Courts and legislators therefore have a central role in ensuring forensic

²² European Court of Human Rights, *S. & Marper v. United Kingdom*, App. Nos. 30562/04 & 30566/04 (Dec. 4, 2008).

science operates within a framework of legality, proportionality, and accountability. The effectiveness of forensic practice ultimately rests on robust institutional capacity, skilled personnel, standardised methods, and judicial scrutiny. Legal and institutional reforms are indispensable to close gaps in infrastructure, expertise, and oversight. When responsibly integrated, forensic and modern tools function not merely as investigative instruments but as protections for justice and the rule of law. In sum, forensic science presents both an opportunity and an obligation for the criminal justice system. Its potential to advance truth-seeking must be matched by commitment to ethical standards, constitutional principles, and human rights. A balanced, rights-respecting application of forensic and modern investigative tools is essential to secure justice in an increasingly complex and technologically driven world.