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From Fingerprints to Fiber Analysis: Unveiling the Silent Witness | The Role of Forensics in Modern Criminal Investigations

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ABSTRACT

Forensic science is usually defined as the application of science to the process of investigation. The forensic scientists use their knowledge and skills to collect, analyze, and interpret evidence to provide information that can be used in the court of law. Forensic science has a massive role in modern criminal investigations, transforming seemingly insignificant details into props of justice delivery. Forensic science is complex and an ever-evolving field. New technologies that can be used to analyse evidence far more quickly and accurately are constantly being developed. This results in forensic science playing a vital role in the criminal justice system. Although these new technologies provide a ton of other problems that can derail the justice system, forensic science continues to be one of the most essential stakeholders in the criminal justice system, and the study of the same can give an idea as to what the propensity of the problems are and how that can be resolved. This article delves into the various types of forensic evidence. It underscores the importance of properly collecting and processing evidence, maintaining the chain of custody, and adhering to ethical considerations to ensure the reliability and admissibility of evidence in court. This article explores various forensic disciplines like toxicology, ballistics, and pathology, highlighting their unique operations in the criminal justice system. The article acknowledges the ethical concerns surrounding the potential for human error and bias in forensic analysis. It emphasises the need for continuous improvement in protocols, training, and quality control to ensure the integrity and objectivity of forensic science in the pursuit of justice.

Keywords: forensic science, evidence, criminal justice, crime scene, DNA.

I. INTRODUCTION

The term ‘Forensic’ is derived from the Latin phrase ‘Forensis’, which is related to the courts of law, discussions, and debates about laws in the public domain. The Black’s Law Dictionary defines forensics as “belonging to the courts of justice.” As a result, forensic science is widely described as a scientific subject that assists the criminal justice system in analysing the scenes

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of crimes and anything related to the crime, such as any valuable item identified and evaluated physically using the existing concepts and methodologies of all material sciences.

The laws of evidence worldwide define numerous fields of forensic science as “technical or other specialised knowledge” that the courts analyze as per their legal criteria using different reliability standards. In this historical context, the standard definition of forensic science is “scientific, technical, or other specialised knowledge,” which assists the courts in determining the factual matters of individual cases, particularly criminal cases².

It is assumed that forensic science is the sole discipline that brings all areas of science to the common man and aids the criminal justice system, which strives to offer a crime-free society for ordinary people to live in.

Forensic science employs the fundamental principles of all physical and scientific sciences. It has developed several fields, including anthropometry, fingerprints, ballistics, handwriting, computers, DNA, brain mapping, narcotics analysis, polygraph, etc. Basic sciences linked with forensic science include forensic biology and serology, forensic chemistry, forensic physics, toxicology, odontology, forensic psychology, forensic DNA, forensic engineering, and cyber forensics. These fields offer reliable scientific help to the criminal justice system³.

II. TYPES OF FORENSIC EVIDENCE

There are 3 types of Forensic Evidence- Biological Evidence, Trace Evidence, Digital Evidence

(A) Biological Evidence

Any substance of biological origin discovered at a crime scene is known as Biological Evidence in the purview of Forensic Science. This includes various elements such as hair, saliva, body fluids, etc. Upon analysis of this evidence, forensic experts can determine the timeline of events in the crime, identify the persons engaged, and recreate the crime. Biological shreds of evidence are very important in forensic investigations as they give powerful and substantive proof in the court of law for the better perusal of justice.⁴

DNA- Deoxyribonucleic Acid are the building blocks of all organisms and are the basic unit of identity, unique to all human beings. DNA is often left at the crime scenes by the perpetrator,

² Wecht CH and Rago JT, *Forensic Science and Law* (CRC Press 2005)

³ Sharma BR, *Forensic Science in Criminal Investigation & Trials* (2020)

⁴ “Crime Scene and DNA Basics for Forensic Analysts | Types of Evidence | National Institute of Justice” (National Institute of Justice) <<https://nij.ojp.gov/nij-hosted-online-training-courses/crime-scene-and-dna-basics-forensic-analysts/evidence-crime-scene/types-evidence>>

and it can be used to identify the presence of individuals at the crime scene. PCR(Polymerase Chain Reaction) amplification is used to create copies of the DNA that help determine who owns the DNA, which, in short, helps identify persons present at the crime scene⁵.

Fingerprints- The ridges and valleys on our fingertips are unique to every human being, leaving behind invisible traces when we touch an object. Forensic experts meticulously collect these “latent” prints at crime scenes using various methods. Then, these prints are examined by trained experts to analyze the details like loops, whorls, and branches, which are then compared to known fingerprints in databases or fingerprints taken from suspects. This meticulous comparison allows the investigating officers to link individuals to crime scenes. Fingerprints provide robust evidence in investigations and have been a cornerstone of forensic science for over a century⁶.

(B) Trace Evidence

Trace evidence comprises minute materials transferred or left behind at the crime scene during the commission of criminal activities. Despite their insignificant look, these diminutive objects can harbour valuable clues to establish connections in a crime. Many types of Trace Evidence exist, such as Fibers, Glass shards, soil, paint chips, etc.⁷

Fibers- Certain microscopic threads fall off clothing, carpets, furniture, and other textile surfaces, which can be used to analyse and discover the source material such as nylon, cotton, wool, etc., which can be used to link a suspect to the crime potentially based on the distinctive traits or dyes of the material.

Soil- Dirt particles travel from shoes, clothes, tyres, or tools to the crime scene; forensic scientists use these to determine the origin of a suspect or object. They do this by analysing the soil composition, including mineral content, pollen, and other components, and comparing it with the soil samples from other regions.

(C) Digital Evidence

Digital forensics uses scientifically validated tools and procedures to recover electronic/digital media data.⁸ Digital evidence encompasses any information stored or transmitted electronically relevant to a legal investigation. Digital evidence has become crucial in forensic science as our lives increasingly rely on technology.

⁵ Bell S and Butler JM, Understanding Forensic DNA (Cambridge University Press 2022)

⁶ Daluz HM, Fundamentals of Fingerprint Analysis, Second Edition (CRC Press 2018)

⁷ Sharma BR, Forensic Science in Criminal Investigation & Trials (2020)

⁸ Panigrahi A, “Cyber Crime & Computer Forensics” (2022) 4 Indian Journal of Law and Legal Research

Electronic Devices- Computers, smartphones, tablets, and other digital devices may store various data, such as emails, text messages, browser history, documents, and even erased data. Forensic investigators can extract and analyse this information to discover communication patterns, probable criminal behaviour, and geographical histories.

Social Media Activity- Social media activity: Social media platforms provide a view into an individual's online profile, which may expose their activities, affiliations, and geographical information. Investigators can collect valuable leads and intelligence by analysing social media postings, communications, and account activity.

III. COLLECTION AND PROCESSING OF FORENSIC EVIDENCE

Collecting and processing evidence in forensic science is significant as it helps build a solid case. The improper handling of forensic evidence can compromise the integrity of evidence, potentially rendering it useless in the courts of law. The Evidence must be appropriately handled without any scope of contamination, i.e., when the evidence comes into contact with other foreign materials, its analysis can become complex, leading to misleading results.⁹

(A) Chain of Custody

One of the most important steps or procedures in collecting and processing forensic evidence is the chain of custody, which is a chronological record documenting every transfer of evidence from collection to analysis and court presentation. The chain of custody is the most critical step of evidence documentation.¹⁰ It is critical to satisfy the court of law that the evidence is authentic and free from alterations. The chain of custody establishes that the evidence was always in the hands of a responsible authority assigned to look after it and was never unaccounted for. Although this is a lengthy procedure, it is necessary for a shred of evidence to be substantial in a court of law.¹¹ A broken chain of custody can lead to a failure to provide justice. A paper trail must be kept so those in control of the evidence may be easily identified and called upon to testify in court if required. When a proper chain of custody is maintained, it prevents police officials and other lab or law officers from tampering with the evidence, as the record of who collected the evidence, who handled it, the period of guardianship of the evidence, and safeguarding conditions while storing it. How a piece of evidence is handed over to the subsequent custodians each time a transfer takes place, and through this record, if any

⁹ *ibid*

¹⁰ Benner J, "Establish a Transparent Chain-of-Custody to Mitigate Risk and Ensure Quality of Specialized Samples" (2009) 7 *Biopreservation and Biobanking* 151 <<http://dx.doi.org/10.1089/bio.2010.0002>>

¹¹ Nair A, *Chain of Custody* (Bitter Lemon Press 2016)

evidence is tampered with, it can be easily traced as to who tampered with the evidence.¹²

Forensic scientists ensure the reliability and validity of the evidence presented in court by adhering to stringent collecting, processing, and analysis processes. This careful & meticulous approach is critical to a fair and just legal system.

IV. EXPLORING FORENSIC DISCIPLINES

1. Forensic Toxicology

Forensic toxicology is the application of toxicology to the field of law. It is the study of biological samples collected from science to identify the presence of toxins, including drugs. The toxicology report gives out important information about the types of drugs present in an individual and whether the amount is safe for a therapeutic dosage or it exceeds a dangerous threshold.¹³ These findings are used to conclude the substance's impact on the person's sickness and mental & physical disability. The process begins with carefully collecting appropriate biological samples to be examined & then these samples are subjected to specific scientific procedures, such as mass spectrometry to identify the presence of toxins, including drugs and poisons. Forensic Toxicology helps to answer crucial questions relating to the cause of death, substance abuse, and the effects of toxins on the actors involved in the particular crime.¹⁴ Forensic toxicologists are called expert witnesses to the court to use their expertise to explain complicated scientific topics in layman's language and present their results based on the particular situation. Forensic toxicology encompasses three significant subdivisions: postmortem, forensic drug testing, and human performance toxicology. Post-mortem toxicology is arguably the most similar to the historical notion of forensic toxicology, which is rife with vivid imagery of elaborate murderous poisonings.¹⁵

2. Forensic Ballistics

Forensic ballistics examines evidence relating to firearms at a crime scene, which studies the ballistic speed, mobility, angular movement, and the effects of projectile units such as bullets, missiles, and bombs. It is a specialised field wherein the details of firearms, their make, model, and any unique markings that might hold significance to a case or hold forensic value are analysed and investigated. Beyond the regular details of the firearms, ballistics forensics also looks at the characteristics of the projectile, wherein the experts meticulously analyse the bullet's class, and characteristics, encompassing its caliber, weight, and type. However, the

¹² Garg R, "Chain of Custody - iPleaders" (iPleaders, June 25, 2022) <<https://blog.iPLEaders.in/chain-of-custody/>>

¹³ Anderson B and others, *Encyclopedia of Toxicology* (Elsevier 2005)

¹⁴ Pope CN and Liu J, *An Introduction to Interdisciplinary Toxicology* (Academic Press 2020)

¹⁵ Cooper G and Negrusz A, *Clarke's Analytical Forensic Toxicology* (Pharmaceutical Press 2013)

actual strength of forensic ballistics rests in its capacity to recognise specific traits. By analysing the distinctive patterns left on the bullet by the barrel's interior, forensic specialists may be able to trace the bullet to a specific firearm, providing vital evidence in criminal cases.¹⁶

3. Forensic Pathology

Forensic pathology is a specialized branch of pathology that investigates deaths under suspicious or unnatural circumstances, e.g., homicides, suicides, accidents, deaths in custody, and wherein unknown reasons cause the death. Forensic Pathologists play a critical role in the criminal legal system as they determine the cause of the death through a post-mortem, also known as an autopsy. The experts in the field establish the circumstances surrounding the death by categorising a death as a homicide, suicide, accident, natural or undetermined, thereby establishing the manner of death.¹⁷ Forensic pathology involves gathering body fluids, tissues, and other trace shreds of evidence for further analysis. Forensic pathologists are often called to court as expert witnesses who explain their findings and conclusions to a jury or judge, playing a significant role in the criminal justice system. Forensic pathology is an essential link between the medical and legal systems, providing critical information on the cause and manner of death in complex instances.¹⁸

4. Digital Forensics

This branch of forensics investigates and analyses digital devices & electronic data to find evidence of criminal activities. It involves collecting, preserving, examining, and analyzing digital information stored on various devices such as computers, mobile phones, servers, and storage media. Digital forensics professionals use specialised tools and procedures to recover and interpret data from digital devices, such as deleted files, internet history, emails, documents, photos, and metadata.¹⁹ The evidence gathered from digital forensics plays a huge role in proving the guilt or innocence of an accused in the court of law in today's changing times. The evidence uncovers motives and helps reconstruct timelines of events. Digital forensic investigations adhere to a strict process to ensure the integrity and admissibility of evidence in court. This entails recording the chain of custody, ensuring forensic soundness,

¹⁶ Blog F and Blog F, "Forensic Ballistics : A Complete Overview - Forensic's Blog" (Forensic's blog, April 8, 2023) <<https://forensicfield.blog/forensics-ballistics/>>

¹⁷ Davis JH, "Forensic Sciences under Scrutiny: Forensic Pathology" (2011) 1 *Academic Forensic Pathology* 396 <<http://dx.doi.org/10.23907/2011.057>>

¹⁸ "What You Need to Know About Forensic Pathology" (College of American Pathologists, August 2, 2022) <<https://www.cap.org/member-resources/articles/what-you-need-to-know-about-forensic-pathology#:~:text=Forensic%20pathology%20is%20a%20subspecialty,referred%20to%20as%20reportable%20deaths.>>

¹⁹ Larson S, "The Basics of Digital Forensics: The Primer for Getting Started in Digital Forensics" [2014] *Journal of Digital Forensics, Security and Law* <<http://dx.doi.org/10.15394/jdfsl.2014.1165>>

complying with legal norms and laws, and creating complete reports outlining findings and analysis. The exponential growth of cyber crimes and digital fraud has propelled digital forensics to the forefront of forensic disciplines in the contemporary era.²⁰

V. FORENSICS AS A STAKEHOLDER IN THE CRIMINAL JUSTICE SYSTEM

“Knowledge of forensic tools and services provides the investigator with the ability to recognize and seize on evidence opportunities that would not otherwise be possible.”

Forensics play a critical role in the criminal justice system by transforming seemingly insignificant details into powerful tools for investigations for the police, which in turn helps build robust cases based on concrete technical evidence for the court of law. Forensic evidence provides a certain sense of objectivity, strengthening the foundation of a criminal case. Forensic evidence transcends traditional subjective witness testimonies by providing more objectivity and certainty through DNA profiling, ballistics study, and the study of toxicology and digital media.

Every crime scene has a lot of tangible evidence & the sort of evidence and where it is located helps the investigators understand the whole crime scenario. Each piece of evidence is vital in exhibiting broad information about the connection between items, people & events in a crime. Further, forensic investigation & analysis serve as a viable way of solving the crime and arresting the perpetrators, and later using the analysis as a substantial piece of evidence in the court of law to get the conviction.

For the prosecutor, forensic science is used to incriminate a criminal. For the defense counsel, forensic science is the enemy against whom a deadly blow must be delivered. Forensic science represents the scale on which guilt or innocence is measured for the judge.²¹

(A) Ethical Concerns

While forensic science & evidence have proved to be revolutionising the criminal justice system by providing it with the luxury of powerful & objective tools for building cases, the ethical concerns regarding their potential for errors & bias in interpretation remain a crucial area of discussion. The primary concern is the likelihood of human error during the forensic procedure. Even though it may look small, it can have disastrous effects, perhaps resulting in false convictions or the release of actual criminals who are dangerous to the community. There also exist concerns regarding biasedness, which might impact the interpretation of the forensic

²⁰ Simplilearn, “What Is Digital Forensics?” (Simplilearn.com, August 8, 2023) <<https://www.simplilearn.com/what-is-digital-forensics-article>>

²¹ Pyrek K, Forensic Science Under Siege (Elsevier 2010)

evidence. These biases may be conscious or unconscious, but the result can be disastrous. One example is confirmation bias, in which the person analysing the data analyses it based on his preconceived notions. Thus, the reading is done in such a way as to prove the preconceived notion, removing the sense of neutrality that is essential for any evidence to be proper. Mitigating these concerns requires a multi-disciplinary prolonged approach & continuous efforts must be made to improve the existing protocols & training to avoid any tunnel vision effect in analysing the most sophisticated shreds of evidence, which potentially can ruin the very purpose of this evidence resulting in a wrong conviction or acquittal which can lead to societal imbalance. By recognising and resolving these ethical problems, the legal system can guarantee that forensic evidence remains trustworthy in the quest for justice.

VI. NAVIGATING THE EVOLVING LANDSCAPE: LANDMARK CASES SHAPING FORENSIC EVIDENCE IN LAW

1. Frye Test(1923)- In *Frye v. United States*,²² the US Court of Appeals established the Frye Test, which required that any scientific evidence, before being submitted as evidence in the court of law, must be widely recognised within the relevant scientific community. This standard was used for decades by the courts of the USA till the Daubert Standard replaced it. [USA]

2. Daubert Standard(1993)- In the case of *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,²³ the US Supreme Court replaced the previously existing norm of the Frye test with the Daubert Standard, which requires the judges to act as “gatekeepers” to ensure that any scientific evidence presented in the court is relevant, reliable, and based on sound scientific principles. [USA]

3. Spencer v. Commonwealth²⁴ (2007) - In Australia, the High Court of Australia addressed the issue of DNA contamination while hearing a case in a high-profile murder trial. The court addressed the contamination issues, stating that DNA contamination is possible and established that there should be clear and compelling evidence to establish the validity of DNA results.[Australia]

4. Mukesh and Ors. v. State (NCT of Delhi) and ors²⁵ (2019)- In this case, the Apex Court of India addressed the significance of proper chain of custody for fingerprint evidence. The court highlighted the need for meticulous documentation to ensure that evidence is reliable and

²² *Frye v. United States* [1923] 293 F. 1013 (D.C. Cir. 1923)

²³ *Daubert v. Merrell Dow Pharmaceuticals, Inc.*[1993] 509 U.S. 579

²⁴ *Spencer v. Commonwealth* [2010] HCA 28

²⁵ *Mukesh and Ors. v. State (NCT of Delhi) and ors*, [2017] 6 SCC 1

authentic when presented in a court of law. This case highlighted the importance of proper protocol in handling forensic evidence in India. [India]

5. Selvi & Ors. v. State of Karnataka²⁶ (2010) - This landmark case dealt with the admissibility of narco analysis, brain mapping, and polygraph tests as evidence in India. The Supreme Court of India highlighted that these pieces of forensic evidence are unreliable and inadmissible in the court, citing lack of scientific validation, thereby accepting them as evidence will have ethical concerns.

It is crucial to emphasise that these are only a few cases worldwide, and the legal environment governing forensic evidence is continually changing. Each country has its legal framework and precedents for determining the admission and interpretation of forensic evidence.

VII. CONCLUSION

Forensic Sciences have transformed the horizons of criminal justice systems worldwide by turning seemingly unimportant facts into potent instruments for delivering justice. Forensic sciences have transcended the limitations of subjective testimonies, offering a bridge to objective and irrefutable evidence by relying on sophisticated methods of evidence collection, thereby strengthening the foundation of the legal system and its pursuit of truth & justice.

However, the future of forensics necessitates a delicate balance between harnessing its inherent potential and addressing the core ethical problems that still exist. The constant danger of human mistake & biasedness highlights the importance of ongoing development in protocols, training, and quality control methods.

Ultimately, the true strength of forensics lies in its fundamental ability to serve as a silent yet powerful tool in upholding the principles of justice by becoming an inseparable stakeholder of the criminal justice system. By acknowledging its limitations, striving towards constant improvement, and prioritising ethical considerations, the future of forensics holds the potential to illuminate the path toward a developed criminal justice system.

²⁶ *Selvi & Ors. v. State of Karnataka* [2010] 7 SCC 263